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a general purpose user-oriented computer
program for analysis of thin-wire structures in
the presence of finite ground.

McCormack, Jerry Wayne

Monterey, California. Naval Postgraduate School

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"ASAP"
ANTENNAS-SCATTERERS ANALYSIS PROGRAM,
A GENERAL PURPOSE USER-ORIENTED COMPUTER
PROGRAM FOR ANALYSIS OF THIN-WIRE STRUCTURES
IN THE PRESENCE OF FINITE GROUND

Jerry Wayne McCormack

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THESIS

"ASAP"

Antennas-Scatterers Analysis Program,
A General Purpose User-Oriented Computer Program For
Analysis of Thin-Wire Structures in the Presence of
Finite Ground

Jerry Wayne McCormack

December 1974

Thesis Advisor:

R. W. Adler

Approved for public release; distribution unlimited.

Prepared for:
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I. INTRODUCTION

Although many thin-wire computer programs have been developed for the purpose of analyzing antennas and scatterers, few of these programs have been directed toward the student of electro-magnetic theory. The majority of the programs are directed to the engineer or advanced student for the purpose of analyzing designed structures or verifying experimental data.

The purpose of the study is to develop a computer program by modifying an existing computer code which can be utilized as an educational method to develop insight into radiating structures by the beginning student of electro-magnetic theory.

The modified Ohio State University Antennas-Scatterers Analysis Program (OSUMOD or ASAP) is directed toward the beginning student who does not yet have the expertise necessary to manipulate the input data for proper execution of the larger more comprehensive analysis program. Even though ASAP is small in core requirements and is fast in run time, it is capable of analyzing structures to assist the engineer with design problems.

Since the resulting program, ASAP, is primarily directed toward students, the program has been limited to structures which contain less than 50 monopoles (segments), no longer than one-fourth of a wavelength, and which have less than 51 nodes (intersections and endpoints). If a ground plane, either perfect or finite is present; the stated limits above are halved due to the generation of an image structure.

II• ORIGINAL PROGRAM

A. THEORY

Reference 1 presents the electro-magnetic theory for the analysis of antennas and scatterers in an isotropic, linear, and homogeneous ambient medium. The analysis is performed in the frequency domain with an excitation caused by either a generator or an incident wave.

In the analysis, a piecewise-sinusoidal expansion is used for the current distribution. The matrix equation $Z I = V$ is generated by enforcing reaction tests with a set of sinusoidal dipoles located in the interior region of the wire. Since the current distribution has the same form as the expansion mode, this formulation is known as the "sinusoidal reaction technique".

B. COMPUTER PROGRAM

Reference 2 presents the computer program corresponding to the theory presented in Ref. 1.

1. Input Format

In the program, the input data must specify the frequency, wire radius, wire conductivity, the parameters of the exterior medium, coordinates of the points to describe the shape and size of the wire configuration, a list of the wire segments, and the indicators for the various outputs. Table 1 is the input data necessary to analyze a half-wave dipole.

2. Output Format

In the original form, the only outputs which could be requested by the input data stream are the following:

a. Antenna Problems

- (1) Current Distribution on the Structure.
- (2) Input Impedance.
- (3) Radiation Efficiency.
- (4) Near-Zone Field.
- (5) Far-Zone Field.

b. Backscattering Problems

- (1) Absorption Cross Section.
- (2) Scattering Cross Section.
- (3) Extinction Cross Section.
- (4) Complex Elements of the Polarization

Scattering Matrix

c. Bistatic Scattering Problems

Echo Area.

Table 2 is an example of the output data available for data of table 1.

3. LIMITATION

Although the program can analyze a structure with up to 50 segments, 55 points and 60 dipoles modes; it can not analyze a structure in the presence of a finite ground plane.

0.002	2.56	-1.0	0.0005		
0.001	1.00	1.0	-1.0	0.0	
1.300.	1.	1.	1.	0	
1	0.	90.	0.	90.	
2	2				3
3	3				45.
4	4				
5	5				
0.	0.	-0.250			
0.	0.	-0.125			
0.	0.	0.			
0.	0.	0.125			
0.	0.	0.250			
0.	0.	1.			
1.	1.				

AN EXAMPLE OF THE INPUT DATA FOR THE ORIGINAL PROGRAM

TABLE 1

98.18	0.0095	82.97	43.26		
-0.091	0.080	-0.091	0.080	0.224	-0.096
0.0	90.0	0.0	1.615		
0.0	90.0	0.0	0.0	0.0	0.608
0.0	0.0069	0.0	0.377	0.0	0.370
45.0	45.0	0.0	0.0	0.0	0.239

AN EXAMPLE OF THE OUTPUT DATA FOR THE ORIGINAL PROGRAM

TABLE 2

III• MODIFIED COMPUTER PROGRAM

A. Input Format

As illustrated in table 1 the format for the input data cards is not self explanatory. This format can be determined by referring to the FORMAT statements of the program of Ref. 2. Since the modified program is directed toward the student, the input data format was changed to allow free format. Reference 2 was written in a form which permitted modifications to allow flexibility in specifying input data for the analysis program. Appendix B, titled "User's Manual", discusses the input data cards necessary for proper execution of an analysis problem. Appendix B is self-contained and may be used independently of the remainder of this document.

B. Output Format

In the original computer program, the absence of labels encumbered the output data and lessened the usefulness of the program. To improve the usefulness of the modified version, detailed labels were added to the output data. As with the input data, Ref. 2 was written in a form which enabled modification to allow more specific output data for the analyzed problem. With the addition of the polar plotting package, the far-zone electric field intensity polar radiation and reradiation patterns can be plotted. A sample problem can be found on page 120 in Appendix B, User's Manual.

C. Finite Ground

To enable the student or the engineer to have an improved analysis program, the finite ground effects were added to ASAP. The theory corresponding to the ground

effects, which utilize Fresnel reflection coefficients, is discussed in Appendix A, titled "System Manual". Also discussed in Appendix A is the modified computer program and the corresponding theory. The electro-magnetic theory was developed in Refs. 1, 2, and 3; and it is restated with its corresponding computer code to assist in the understanding of the methods applied. Appendix A is self-contained and may be used independently of the remainder of this document.

IV• CONCLUSION

The addition of ground effect techniques to the original program did not alter the accuracy or the computational capabilities of the program. The ground effect techniques utilized the results of the original program and modified these results to account for the effects of the presence of the finite ground.

To verify the numerical results of ASAP, the input impedances of both a horizontal and a vertical dipole were compared to the solutions of the exact form of the Sommerfield's equation. As can be seen in table 3 the finite ground treatment of ASAP agrees favorably with Sommerfield's solutions. The ASAP finite ground results are also in excellent agreement with the previous computer solutions of Refs. 4 and 5.

V• RECOMMENDATIONS

Although the program is a general analysis tool for students, several future modifications will enhance the program as a design tool for engineers. These items include: varying the wire radius on the structure; incorporation of

non-radiating elements such as transmission lines; varying the wire insulation radius, conductivity, and dielectric constant; and a geometry generation package such as dipole array or helix. One major change that would both improve the speed and reduce the core requirement is that of symmetry. No attempt was made to utilize the symmetry in the admittance matrix when the ground plane is present. If symmetry were applied, the structure size limit with the ground plane present would be approximately that of the structure without the ground plane.

VERTICAL DIPOLE FREQUENCY 3MHZ LENGTH .5 WAVELENGTH RADIUS .005 METERS DIELECTRIC CONSTANT (RELATIVE) 10				
CONDUCTIVITY	HEIGHT/WAVELENGTH	ASAP		EXACT*
.1	.25	108.43+J	63.22	113.7 +J 56.22
	.30	92.43+J	37.73	93.97+J 32.62
	.35	82.59+J	34.76	83.56+J 29.74
	.45	74.01+J	40.11	74.87+J 35.34
.001	.25	98.74+J	63.52	99.86+J 46.43
	.30	86.15+J	39.02	87.40+J 34.04
	.35	80.15+J	38.08	81.11+J 33.16
	.45	75.42+J	41.79	76.32+J 37.03
.00001	.25	97.94+J	64.86	96.68+J 49.11
	.30	86.12+J	40.85	87.37+J 35.94
	.35	80.82+J	38.89	81.79+J 33.99
	.45	75.93+J	41.55	76.83+J 36.78
HORIZONTAL DIPOLE FREQUENCY 3 MHZ LENGTH .5 WAVELENGTH RADIUS .001 METERS DIELECTRIC CONSTANT (RELATIVE) 10				
CONDUCTIVITY	HEIGHT/WAVELENGTH	ASAP		EXACT*
.1	.5	72.95+J	28.53	78.25+J 23.91
	.3	103.70+J	58.27	117.5 +J 52.05
	.1	30.16+J	69.54	33.20+J 73.65
.001	.5	74.23+J	35.84	80.66+J 31.84
	.3	94.16+J	51.32	105.3 +J 46.01
	.1	54.52+J	62.89	61.31+J 64.33
.00001	.5	76.13+J	35.99	82.79+J 31.73
	.3	91.85+J	53.21	103.0 +J 48.56
	.1	54.30+J	56.81	61.03+J 57.27

* COURTESY OF LAWRENCE LIVERMORE LABORATORY

TABLE 3

APPENDIX A
SYSTEM MANUAL

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SYSTEM MANUAL

INTRODUCTION: The Antennas-scatterers Analysis Program (ASAP) for thin wire structures in a homogenous conducting medium performs a frequency domain analysis of antennas and scatterers. The program is applicable in the presence of a ground either perfect or finite. This appendix will describe the computer program which accomplishes this. Although the program was written for the IBM 360 computer system it can be executed on another system with minor modifications.

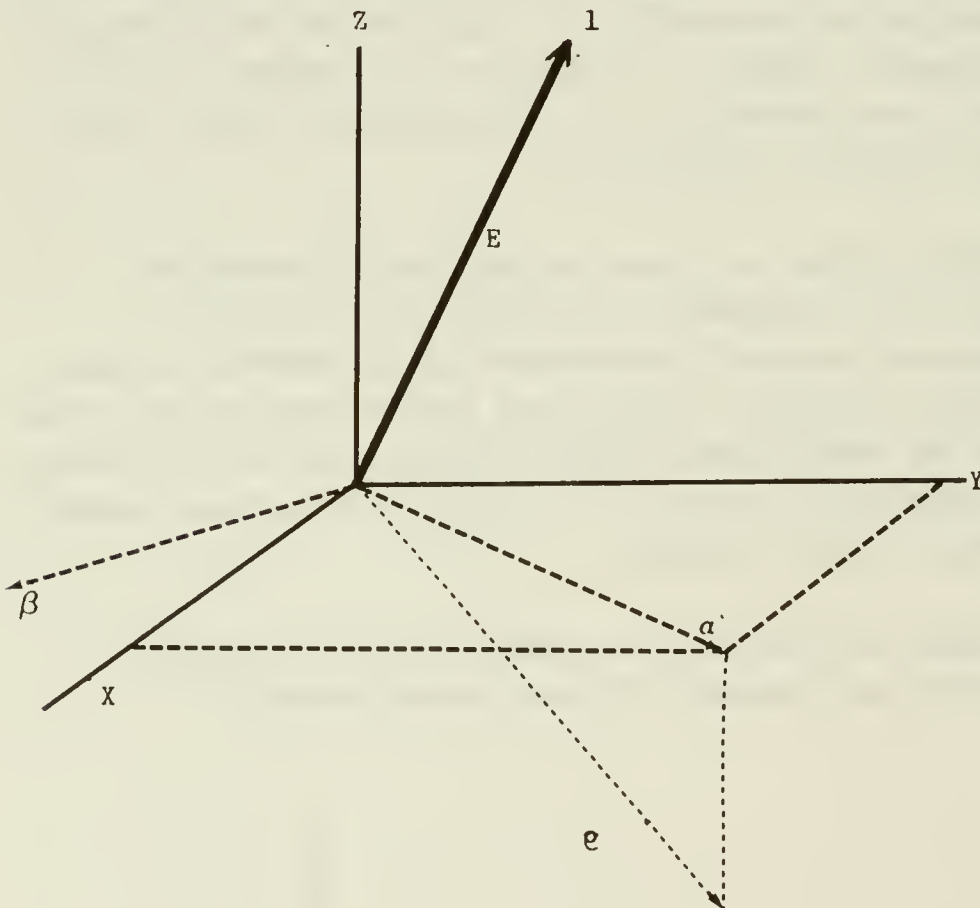
A piecewise-sinusoidal expansion is used for the current distribution. The matrix equation $ZI = V$ is generated by enforcing reaction tests with a set of sinusoidal dipoles located in the interior region of the wire. Since the test dipoles have the same current distribution as the expansion modes, this may be regarded as an application of Galerkin's method. Rumsey's reaction concept was most helpful in this development, and therefore the formulation is known as the "sinusoidal reaction technique".

The main routine and each subroutine is discussed separately in this appendix. The writeups for the subroutines are arranged alphabetically by subroutine name after the main program. Each of the discussions includes the purpose of the subroutine, brief description, and a listing. After the subroutine writeups is a table of the more common symbols used in this program.

The input data and program limits are discussed in detail in the next appendix titled "USERS MANUAL".

GROUND EFFECTS: In the modified antenna analysis computer program finite and infinite ground effects were added by using the reflection coefficient technique. The method in which this technique was used required the generation of an image structure. In this section the reflection technique will be discussed in detail.

In order to apply ground effects to the electric field, the field for the image structure was first calculated as if a ground were not present. Then, the field was decomposed into parallel and perpendicular components. (A parallel component is the component which is parallel to the plane of incidence. A perpendicular component is one which is perpendicular to this plane. The plane of incidence is the plane containing the normal to the reflecting surface and the incident ray.)



Consider an image monopole with the electric field in the l direction. The ray, e , is a vector which is perpendicular to l and passes thru the point of interest. To apply reflection technique, the plane of incident must be found. It is advantageous to define a new coordinate system (α, β, z) where α and β are parallel to the xy plane with α in the plane of incident and β perpendicular.

If the direction cosines ($\cos x$, $\cos y$, and $\cos z$) are known, it can be shown that the components of the field in the $\alpha\beta$ (xy) plane have the following relationship:

$$\begin{bmatrix} E_{||} \\ E_{\perp} \end{bmatrix} = \begin{bmatrix} \cos \phi & \sin \phi \\ \sin \phi & -\cos \phi \end{bmatrix} \begin{bmatrix} E_x \\ E_y \end{bmatrix}$$

where $\phi = \arctan(\cos y / \cos x)$.

Now the reflection coefficients for the interface can be applied as:

$$\begin{aligned} E_{||}(R) &= R_{||} E_{||} \\ E_{\perp}(R) &= R_{\perp} E_{\perp} \end{aligned}$$

where $R_{||}$ and $R_{\perp}$ will be defined later in this section.

Applying the matrix equation above yeilds:

$$\begin{bmatrix} E_x^{(R)} \\ E_y^{(R)} \end{bmatrix} = \begin{bmatrix} \cos \phi & \sin \phi \\ \sin \phi & -\cos \phi \end{bmatrix} \begin{bmatrix} E_{||}^{(R)} \\ E_{\perp}^{(R)} \end{bmatrix}$$

(the square matrix is unique, in that, the inverse is equal to the original matrix). Since the image direction is opposite to the original monopole, that is,

$$(\bar{l} \times \bar{z})_{\text{original}} = - (\bar{l} \times \bar{z})_{\text{image}},$$

the z component of the field, which is in the plane of incident, is given by:

$$E_z^{(R)} = - R_{||} E_z.$$

From electro-magnetic theory the reflection coefficients for the fields in medium (1) at the interface with another medium (2) are defined as:

for parallel

$$R_H = \frac{\cos \theta - \sqrt{\epsilon' - \sin^2 \theta}}{\cos \theta + \sqrt{\epsilon' - \sin^2 \theta}}$$

and for perpendicular

$$R_V = \frac{-\epsilon' \cos \theta + \sqrt{\epsilon' - \sin^2 \theta}}{\epsilon' \cos \theta + \sqrt{\epsilon' - \sin^2 \theta}}$$

where θ is the angle of incident as measured from the normal to the interface and

$$\epsilon' = (\epsilon_2 + \sigma_2/j\omega) / (\epsilon_1 + \sigma_1/j\omega)$$

where the subscripts correspond to the mediums above.

To determine the relationship between $R_{||}$, $R_{\perp}$ and R_V , R_H a perfect ground ($\epsilon_r = 0$, $\sigma = \infty$) was investigated.

$$\lim_{H \rightarrow \infty} R_H = -1$$

$$\lim_{V \rightarrow \infty} R_V = +1$$

But, for a perfect ground the contributions to the field from the image monopole would be equal to the field of the original monopole but opposite in sign due to the chosen reference direction,

$$E_{||}^{(R)} = R_{||} E_{||} = - E_{||}$$

$$E_{\perp}^{(R)} = R_{\perp} E_{\perp} = - E_{\perp}$$

therefore

$$R_{||} = R_H$$

$$R_{\perp} = - R_V$$

In summary, the contribution to the electric field of a monopole over a ground plane at a given point is given by:

$$E^{(R)} = E_x^{(R)} \cos x + E_y^{(R)} \cos y + E_z^{(R)} \cos z$$

where

$$\begin{aligned} E_x^{(R)} &= R_{\perp} E \cos x + (R_{||} - R_{\perp}) E \cos x \cos^2 \phi \\ &+ (R_{||} - R_{\perp}) E \cos y \sin \phi \cos \phi \end{aligned}$$

$$E_y^{(R)} = R_{||} E \cos y - (R_{||} - R_{\perp}) E \cos y \cos^2 \phi \\ + (R_{||} - R_{\perp}) E \cos x \sin \phi \cos \phi$$

$$E_z^{(R)} = - R_{||} E \cos z$$

where E is the field without the ground plane present and

$$R_{||} = \frac{-\epsilon' \cos \theta + \sqrt{\epsilon' - \sin^2 \theta}}{\epsilon' \cos \theta + \sqrt{\epsilon' - \sin^2 \theta}}$$

$$R_{\perp} = \frac{\cos \theta - \sqrt{\epsilon' - \sin^2 \theta}}{\cos \theta + \sqrt{\epsilon' - \sin^2 \theta}}$$

$$\epsilon' = \epsilon_r - j(\sigma/\epsilon_0 \omega)$$

MAIN

PURPOSE: to control the input, output, and the flow of calculations.

METHOD: The main program controls the flow of the required calculations by calling only a few subroutines. These subroutines in turn call other subroutines which actually do the required calculations. The order of the calling sequence is diagramed after the listing for the main program.

The DIMENSION statements at the beginning of the main routine provides the required storage for a wire structure with up to 50 segments, 60 nodes and 60 dipoles without the presence of a ground plane. If a ground plane is present one-half of the reserved storage is required for the image, therefore a wire structure with up to 25 segments and 30 nodes can be analyzed.

NM denotes the actual number of monopoles (segments), INM is the corresponding dimension, and the dimension for CG, VG, and ZLD is twice INM. The second subscript for MD always has a dimension of 4 to correspond to the number of segments meeting at a given node.

N denotes the number of simultaneous linear equations and ICJ is the corresponding dimension. The dimension for C is $(ICJ * ICJ + ICJ) / 2$.

In the statements above statement 4, the initial conditions and defaults are established. After calling subroutine READ to determine the input parameters, the IF statements output the parameters to be used for the calculations. In the DO LOOP ending at statement 7, the the input data of the structure geometry is stored in order

to recall if the structure is to be moved for ground plane calculations.

After the image structure is generated and structure location is moved, subroutine SORT is called to determine the dipole modes. Prior to calling SGANT, the load and generator information is established.

Subroutine SGANT is then called to calculate the elements of the impedance matrix. If FEEDS or GENERATORS are specified by the input data stream, subroutine GANT1 is called to solve for the current distribution due to these forcing functions.

In the DO LOOP ending with statement 29, subroutine GNFLD is called to calculate the near-zone field for the current distribution of the subroutine GANT1.

The subroutine GFFLD is called for the far-zone field of the current distribution of the subroutine GANT1 in the DO LOOP ending at statement 35. The subroutine GFFLD is called again in DO LOOPS ending at statements 42 and 51, if bistatic and backscattering calculations are requested by the input data stream.

CALLS TO: GANT1

 GFFLD

 GNFLD

 POLPRT

 READ

 SGANT

 SORT


```

DIMENSION X(60), Y(60), Z(60), XG(60), YG(60), ZG(60)
DIMENSION I1(60), I2(60), I3(60), JA(60), JB(60), KFLAG(30)
DIMENSION CPH(500), CTHT(500)
DIMENSION DATY1(360), DATY2(360), DATY3(360), DATY4(360)
DIMENSION D(50), (A(50), B(50), ISC(50), M(50,4), ND(50)
DIMENSION LZD(60), KGEN(60)
DIMENSION XNP(50), YNP(50), ZNP(50)
COMPLEX C(1830)
COMPLEX COAT1(500), COAT2(500), COAT3(500), COAT4(500)
COMPLEX CJ(60), EP(60), EPP(60), ET(60), ETT(60)
COMPLEX CGD(50), SGD(60), CGI(100), VG(100), ZLO(100)
COMPLEX VOLT(60), ZLDD(60)
COMPLEX EPPS, EPT, ETPS, ETTS, EX, EY, EZ
COMPLEX EP2, EP3, EP4, ERR, ETA, GAM, Y11, Z11, Z5
DATA PI, TP/3.14159, 6.28318/
DATA EO, UO/8.854E-12, 1.2566E-6/
1 NGEN = -1
  IGRD = -1
  LGAD = -1
  BM = -1
  ICARD = 0
  AM = -1
  IFLAG = 0
  VOLT(1) = (1., 0.)
  HGT = 0.
  NM = 0
  NP = 0
  MSG = 0
  SIG2 = -1.
  T02 = -1.
  SIG3 = -1
  ER3 = 1
  TD3 = 0.
  CMM = 50.
  ER2 = 1.
  FMC = 300.
  INM = 50
  CJ = 60
  WRITE (6, 74)
C
  DO 2 I=1, 30
C
C
    DO 3 J=1, INM
      ISC(J) = 0
      VG(J) = (0., 0)
      ZLO(J) = (0., 0)
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
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76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
3 ZLO(JJ) = (0., 0)
4 NFFP = 0
  NBIP = 0
  NRAP = 0
  AFFP = 1000.
  AFFT = 1000.
  ARIP = 1000.
  ABIT = 1000.
  ABAP = 1000.
  ABAT = 1000.
  STEP = 1.
  KNM = 0
  CALL READ (IA, IB, (BISC, ICARD, IGAIR, IGRD, (NEAR, INT, ISCAT, IWR, IFLAG,
    IKFLAG, KGEN, LGAD, LZD, MSG, NBAP, NBIP, NFFP, NGEN, NM, NP, ABAP, ABAT, AFFP,
    2FFI, AD(P, ABIT, AM, BM, CMM, ER2, ER3, ER4, FMC, HGT, PHAF, PHAI, PHIF, PH1, PH
    3SF, PHSI, JHAF, THA1, THIF, TH11, THSF, THS1, SIG2, SIG3, SIG4, T02, T03, VOLT,
    4X, XNP, Y, YNP, Z, ZLDD, ZNP, STEP)
  WRITE (6, 56)
  IF (MSG.LT.1) GO TO 5
  IF (MSG.EQ.1) WRITE (6, 70) KFLAG(30)
  IF (IFLAG.EQ.4) GO TO 1
  IF (IFLAG.EQ.5) STOP
  IF (AM.LT.0) WRITE (6, 127)
  IF (AM.LT.0) GO TO 6
  IF ((INM.GT.0).AND.(NP.GT.0)) GO TO 7
  WRITE (6, 116)
  IF (IFLAG.EQ.1) GO TO 1
  MSG = 2
  GO TO 4
  IF (KFLAG(1).EQ.1) WRITE (6, 83) FMC
  IF (KFLAG(2).EQ.1) WRITE (6, 84) AM
  IF (KFLAG(3).EQ.1) WRITE (6, 85) CMM
  IF (KFLAG(20).NE.1) WRITE (6, 87)
  IF (KFLAG(4).EQ.1) WRITE (6, 86) BM
  IF (KFLAG(4).EQ.1) WRITE (6, 88) BM
  IF (KFLAG(5).EQ.1) WRITE (6, 89) SIG2
  IF (KFLAG(6).EQ.1) WRITE (6, 90) ER2
  IF (KFLAG(7).EQ.1) WRITE (6, 91) TD2
  IF (KFLAG(8).NE.1) WRITE (6, 92)
  IF (KFLAG(9).EQ.1) WRITE (6, 93) SIG3
  IF (KFLAG(10).EQ.1) WRITE (6, 94) ER3
  IF (KFLAG(11).EQ.1) WRITE (6, 95) T03

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97 IF (KFLAG(26).NE.1) WRITE (6,122)
98 IF ((IGPO.EQ.1).AND.(KFLAG(25).EQ.1)) WRITE (6,123)
99 IF ((IGPO.EQ.1).AND.(KFLAG(25).EQ.1)) WRITE (6,125)
100 IF ((IGPO.GT.1).AND.(KFLAG(25).EQ.1)) WRITE (6,124) ER4,SIG4
101 IF ((IGRO.GT.0).AND.(KFLAG(25).EQ.1)) WRITE (6,126) HGT
102 IF (KFLAG(21).EQ.1) WRITE (6,121) INT
103 WRITE (6,111)
104 IF (KFLAG(12).EQ.1) WRITE (6,96) (1,1A(1),X(1A(1)),Y(1A(1)),Z(1A(1)
105 ),1B(1),X(1B(1)),Y(1B(1)),Z(1B(1)),I=1,NM)
106 WRITE (6,111)
107 IF (KFLAG(24).GT.0) WRITE (6,119) (LZO(1),ZLLO(1),I=1,LOAO)
108 IF (KFLAG(14).GT.0) WRITE (6,118) (LZO(1),ZLLO(1),I=1,LOAO)
109 WRITE (6,111)
110 IF (KFLAG(23).GT.0) WRITE (6,120) (KGEN(1),VOLT(1),I=1,NGEN)
111 IF (KFLAG(13).GT.0) WRITE (6,97) (KGEN(1),VOLT(1),I=1,NGEN)
112 WRITE (6,111)
113 WRITE (6,114)
114 WRITE (6,93)
115 WRITE (6,112)
116 IF (KFLAG(22).NE.1) WRITE (6,110)
117 IF (KFLAG(15).EQ.1) WRITE (6,99)
118 IF (KFLAG(16).EQ.1) WRITE (6,100) PHA1,PHA2,THA1,THA2,STEP
119 IF (KFLAG(17).EQ.1) WRITE (6,101) PHI1,PHI2,THI1,THI2,STEP
120 IF (KFLAG(18).EQ.1) WRITE (6,102) PHS1,PHS2,THS1,THS2,STEP
121 IF (KFLAG(19).EQ.1) WRITE (6,103) (XNP(1),YNP(1),ZNP(1),I=1,INEAR)
122 IF (AFFP.LT.500.) WRITE (6,105) AFFP
123 IF (AFFT.LT.500.) WRITE (6,104) AFFT
124 IF (ABAP.LT.500.) WRITE (6,109) ABAP
125 IF (ABAT.LT.500.) WRITE (6,108) ABAT
126 IF (ABIP.LT.500.) WRITE (6,107) ABIP
127 IF (ABIT.LT.500.) WRITE (6,106) ABIT
128 IF (118(SC.GT.0).AND.(ISCAT.LT.0)) WRITE (6,73)
129 FHZ = FMC*1.E6
130 OMEGA = TP*FHZ
131 IF (SIG2.LT.0.) EP2=ER2*EO*CMPLX(1.,-T02)
132 IF (T02.LT.0.) EP2 = CMPLX(ER2*EO,-SIG2/OMEGA)
133 IF (SIG3.LT.0.) EP3=ER3*EO*CMPLX(1.,-T03)
134 IF (T03.LT.0.) EP3 = CMPLX(ER3*EO,-SIG3/OMEGA)
135 IF (IGRO.GT.1) EP4 = CMPLX(ER4*EO,-SIG4/OMEGA)
136 IF (IGPO.GT.1) ERR = EP4/EP3
137 IF (KFLAG(21).GT.0) WRITE (6,121) INT
138 ETA = CSQRT(UO/EP3)
139 GAM = OMEGA*CSQRT(1-UO*EP3)
140 IF (KFLAG(12).NE.1) GO TO 9
141 NPG = NP
142 NMG = NM
143
C DO 8 I=1,NPG
144
145
146 XG(I) = X(I)
147 YG(I) = Y(I)
148 ZG(I) = Z(I)
149
C
C 9 DO 10 I=1,NPG
150 X(I) = XG(I)
151 Y(I) = YG(I)
152 Z(I) = ZG(I)
153
C
C NP = NPG
154 NM = NMG
155 IF (IGPO.LE.0) GO TO 15
156 SFT UP (IMAGE FOR GROUND PLANE)
157 ZMIN = Z(I)
158 IWL = 0
159 K = 0
160
C
C DO 11 I=1,NP
161 IF (Z(I).LT.ZMIN) ZMIN=Z(I)
162 Z(I) = Z(I)*HGT
163 IF (Z(I).GT.1.E-60) GO TO 11
164 IWL = IWL+1
165 11 CONTINUE
166
C IF (ZMIN.LE.HGT) GO TO 12
167 WRITE (6,117)
168 IF (IFLAG.EQ.1) GO TO 1
169 IF (IFLAG.EQ.2) STOP
170 MSG = 2
171 GO TO 4
172
C
C 12 DO 13 J=1,NM
173 K = J+NM
174 1A(K) = 1A(J)
175 IF (1A(J).GT.(IWL)) 1A(K)=1A(J)+NP-IWL
176 13 1B(K) = 1B(J)+NP-IWL
177
C IWL = IWL+1
178
C
C ON 14 I=IWL,NP
179 J = I+NP-IWL
180 X(IJ) = X(I)
181 Y(IJ) = Y(I)
182 Z(IJ) = -Z(I)
183
C
C KNM = NM+1
184 NM = 2*NM
185

```

	NP = 2*NP-JWL	193
15	CALL SORT (IA,18,11,12,13,JA,J8,MO,NO,NM,NP,N,MAX,MIN,1CJ,1NMI	194
	IF (MAX.LE.4) GO TO 16	195
	WRITE (6,71)	196
	IF ((FLAG.EQ.1) GO TO 1	197
	IF ((FLAG.EQ.2) STOP	198
	MSG = 2	199
	GO TO 4	200
16	IF (MIN.GE.1) GO TO 17	201
	WRITE (6,72)	202
	IF ((FLAG.EQ.1) GO TO 1	203
	IF ((FLAG.EQ.2) STOP	204
	MSG = 2	205
	GO TO 4	206
17	WRITE (6,56)	207
	IF (MAX.GT.4.OR.MIN.LT.1.OR.N.GT.1CJ) GO TO 54	208
	I12 = 1	209
	IF (LOAD.GT.0) GO TO 19	210
C		211
	DO 18 I=1,NM	212
	18 ZLD(I) = (0.,0.)	213
C		214
	19 IF (NGEN.GT.0) GO TO 21	215
C		216
	DO 20 I=1,NM	217
	20 VG(I) = (0.,0.)	218
C		219
	21 KN = NM	220
	IF (IGRO.GT.0) KN = NM/2	221
	J = 1	222
C	ANTENNA CALCULATIONS	223
	IF (LOAD.LE.0) GO TO 24	224
	IF (KFLAG(24).GT.0) GO TO 22	225
C		226
	DO 23 J=1,KN	227
C		228
	22 DO 23 I=1,LOAD	229
	K = ZLD(I)	230
	IF ((IA(J).EQ.K).AND.(KFLAG(14).GT.0)) ZLO(IJ)=ZLD(I)	231
	IF (KFLAG(24).GT.0) ZLD(K)=ZLD(I)	232
	IF (KFLAG(14).GT.0).AND.(IGRO.GT.0) ZLO(J+KN)=ZLO(J)	233
	IF (KFLAG(24).GT.0).AND.(IGRO.GT.0) ZLD(K+KN)=ZLD(K)	234
	IF (IGRO.LE.0) GO TO 23	235
	IF (K.LE.1WL).AND.(KFLAG(14).GT.0) ZLD(J+KN)=(0.,0.)	236
	IF ((IA(J).LE.1WL).AND.(KFLAG(24).GT.0) ZLD(K+KN)=(0.,0.)	237
23	CONTINUE	238
C		239
	24 IF (NGEN.LT.0) GO TO 27	240
	KN = NM	241
	IF (IGRO.GT.0) KN = NM/2	242
	J = 1	243
	IF (KFLAG(23).GT.0) GO TO 25	244
C		245
	DO 26 J=1,KN	246
C		247
	25 DO 26 I=1,NGEN	248
	K = KGEN(I)	249
	IF ((IA(IJ).EQ.K).AND.(KFLAG(13).GT.0) VG(IJ)=VOLT(I)	250
	IF (KFLAG(23).GT.0) VG(K)=VOLT(I)	251
	IF (KFLAG(13).GT.0).AND.(IGRO.GT.0) VG(IJ+KN)=VG(IJ)	252
	IF (IGRO.LE.0) GO TO 26	253
	IF (K.LE.1WL).AND.(KFLAG(13).GT.0) VG(IJ+KN)=(0.,0.)	254
	IF ((IA(IJ).LE.1WL).AND.(KFLAG(23).GT.0) VG(K+KN)=(0.,0.)	255
26	CONTINUE	256
C		257
	27 CALL SGANT (IA,18,1NM,1SC,11,12,13,JA,J8,MO,N,NO,NM,NP,AM,8M,C	258
	1,CGD,CM,0,EP2,EP3,ETA,FH2,GAM,SGO,X,Y,Z,ZLO,ZS,ERR,IGRO)	259
	IF (N.GT.0) GO TO 28	260
	IF ((FLAG.EQ.2) STOP	261
	MSG = 2	262
	IF ((FLAG.EQ.1) GO TO 1	263
	GO TO 4	264
28	IF (NGEN.LE.0) GO TO 36	265
	WRITE (6,75)	266
	WRITE (6,76)	267
	WRITE (6,77)	268
	WRITE (6,82)	269
	CALL GANT (IA,18,1NM,1WR,11,12,13,112,JA,J8,MO,N,NO,NM,AM,C,CJ,CG	270
	1,CM,0,EFF,GAM,GG,CGD,SGO,VG,V11,Z11,ZLO,ZS,IGRO)	271
	WRITE (6,5) EFF,GG,Z11	272
C	NEAR FIELD	273
	IF (INFR.LE.0) GO TO 30	274
	WRITE (6,75)	275
	WRITE (6,78)	276
	WRITE (6,77)	277
C		278
	DO 29 I=1,INEAR	279
	XP = XNP(I)	280
	YP = YNP(I)	281
	ZP = ZNP(I)	282
	CALL GNFLD (IA,18,1NM,11,12,13,MO,N,NO,NM,AM,CGD,SGD,ETA,GAM,CJ,D,	283
	1,X,Y,Z,XP,YP,ZP,EX,EY,EZ,IGRO,ERR)	284
	WRITE (6,58) XP,YP,ZP	285
	WRITE (6,59) EX,EY,EZ	286
29	CONTINUE	287
C		288

C	FAR FIELD	289
30	IF (IGAIN.LE.0) GO TO 36	290
C	OO 31 I=1,360	291
	OATY1(I) = 0	292
	OATY2(I) = 0	293
	OATY3(I) = 0	294
31	OATY4(I) = 0	295
C	WRITE (6,75)	296
	WRITE (6,79)	297
	WRITE (6,77)	298
	WRITE (6,82)	299
	INC = 0	300
	NPL = -1	301
	IF (KFLAG(I6).EQ.1) WRITE (6,691	302
	IF (NFFP.EQ.1) GO TO 32	303
	NPHA = (PHAF-PHAI)/STEP+1	304
	NTHA = (THAF-THAI)/STEP+1	305
	GO TO 34	306
32	IF (AFFT.GT.500.) GO TO 33	307
	NPL = 1	308
	NPHA = 360	309
	NTHA = 1	310
	PHAI = 0.	311
	THAI = AFFT	312
	STEP = 1.	313
	GO TO 34	314
33	NPL = 2	315
	NPHA = 1	316
	NTHA = 360	317
	PHAI = AFFP	318
	THAI = 0.	319
	STEP = 1.	320
34	PH = PHAI-STEP	321
	OO 35 K=1,NPHA	322
	PH = PH+STEP	323
	TH = THAI-STEP	324
	OO 35 I=1,NTHA	325
	PHSPH = 0.	326
	PHSTH = 0.	327
	TH = TH+STEP	328
	IF ((IGRO.GT.0).AND.((TH.GT.90).AND.(TH.LT.270))) GO TO 35	329
	CALL GFFLO (IA,IB,INC,INM,IWR,I1,I2,I3,I12,MO,N,NO,NM,AM,ACSP,ACST	330
	I,CGO,CG,CJ,CMM,CECSP,ECST,EP,ET,EPP,ETT,EPPS,ETPS,ETTS,CG,	331
	2GPP,GTI,PH,SGO,SCSP,SCST,SPPM,SPTM,STPM,STM,TH,X,Y,Z,ZLO,ZS,ETA,G	332
	3AM,ERR,IGRD)	333
	ETMAG = CABS(ETTS)	334
		335
		336
	ETMAG = CABS(EPPS)	337
	IF (ETMAG.GT.1.E-32) PHSTH=57.295779*ATAN2(AIMAG(ETTS),REAL(ETTS))	338
	IF (ETMAG.GT.1.E-32) PHSPH=57.295779*ATAN2(AIMAG(EPPS),REAL(EPPS))	339
	IF (NPL.EQ.1) DATY1(K)=ETMAG	340
	IF (NPL.EQ.1) DATY2(K)=ETMAG	341
	IF (NPL.EQ.2) DATY1(I)=ETMAG	342
	IF (NPL.EQ.2) DATY2(I)=ETMAG	343
	IF (KFLAG(I6).NE.1) GO TO 35	344
35	WRITE (6,60) TH,PH,GTI,GPP,ETTS,ETMAG,PHSTH,EPPS,ETMAG,PHSPH	345
	CONTINUE	346
C	WRITE (6,56)	347
	IF (NPL.LE.0) GO TO 36	348
	CALL POLPRT (1,OATY1)	349
	CALL POLPRT (2,OATY2)	350
C	BACK SCATTERING	351
36	IF (ISCAT.LE.0) GO TO 54	352
	WRITE (6,75)	353
	WRITE (6,80)	354
	WRITE (6,77)	355
	WRITE (6,82)	356
	L = 0	357
	NPL = -1	358
	INC = 1	359
	IF (NBAP.EQ.1) GO TO 37	360
	NPHI = (PHIF-PHI1)/STEP+1	361
	NTHI = (THIF-THI1)/STEP+1	362
	IF (IWR.LE.0) WRITE (6,62)	363
	GO TO 39	364
37	IF (ABAT.GT.500.) GO TO 38	365
	NPL = 1	366
	NPHI = 360	367
	NTHI = 1	368
	PHI1 = 0.	369
	THI1 = ABAT	370
	STEP = 1.	371
	GO TO 39	372
38	NPL = 2	373
	NPHI = 1	374
	NTHI = 360	375
	PHI1 = ABAP	376
	THI1 = 0.	377
	STEP = 1.	378
39	PH = PHI1-STEP	379
C	OO 42 K=1,NPHI	380
	PH = PH+STEP	381
	TH = THI1-STEP	382
		383
		384

C	DO 42 I=1,NTH1	385
	TH = TH+STEP	386
	IF ((1/CRO.GT.0).AND.11TH.GT.90).AND.(TH.LT.270))) GO TO 42	387
	L = L+1	388
	CALL GFFLO (1A,18,INC,INM,IWR,11,12,13,112,MO,N,NO,NM,AM,ACSP,ACST	389
	1,C,CGD,CG,CJ,CMM,O,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ETTS,GG,	390
	2CPP,GT1,PH,SGD,SCSP,SCST,SPPH,SPTH,STPH,STTM,TH,X,Y,Z,ZLO,ZS,ETA,G	391
	3AM,ERR,IGRO)	392
	IF (IWR.GT.0) GO TO 40	393
	IF (NPL.LT.0) WRITE (6,63) PH,TH,SPPH,SPTH,STPH,STTM,ACSP,ACST,ECS	394
	IP,ECST,SCSP,SCST	395
40	CPII(L) = PH	396
	CTHET(L) = TH	397
	COAT1(L) = EPPS	398
	COAT2(L) = EPTS	399
	COAT3(L) = ETPS	400
	COAT4(L) = ETTS	401
	IF (NPL.NE.1) GO TO 41	402
	DATY1(K) = CABS(EPPS)	403
	DATY2(K) = CABS(EPTS)	404
	DATY3(K) = CABS(ETPS)	405
	DATY4(K) = CABS(ETTS)	406
	GO TO 42	407
41	DATY1(I) = CABS(EPPS)	408
	DATY2(I) = CABS(EPTS)	409
	DATY3(I) = CABS(ETPS)	410
	DATY4(I) = CABS(ETTS)	411
42	CONTINUE	412
C	WRITE (6,82)	413
	IF (NPL.LE.0) GO TO 43	414
	CALL POLPRT (7,DATY1)	415
	CALL POLPRT (8,DATY2)	416
	CALL POLPRT (9,DATY3)	417
	CALL POLPRT (10,DATY4)	418
	IF (KFLAG17.NE.1) GO TO 45	419
43	WRITE (6,64)	420
C	DO 44 I=1,L	421
44	WRITE (6,65) CPII(I),CTHET(I),COAT1(I),COAT2(I),COAT3(I),COAT4(I)	422
C	BISTATIC SCATTERING	423
45	IF ((BISC.LE.0) GO TO 54	424
	WRITE (6,75)	425
	WRITE (6,81)	426
	WRITE (6,77)	427
	WRITE (6,82)	428
	WRITE (6,61) CPII(L),CTHET(L)	429
	WRITE (6,82)	430
	L = 0	431
	INC = 2	432
	NPL = -1	433
	IF (NBIP.EQ.1) GO TO 46	434
	NPHS = (PHSF-PHS1)/STEP+1	435
	NTHS = (THSF-THS1)/STEP+1	436
	IF (IWR.LE.0) WRITE (6,67)	437
	GO TO 48	438
46	IF (ABIT.GT.500.) GO TO 47	439
	NPL = 1	440
	NPHS = 360	441
	NTHS = 1	442
	PHS1 = 0.	443
	THS1 = ABIT	444
	STEP = 1.	445
	GO TO 48	446
47	NPL = 2	447
	NPHS = 1	448
	NTHS = 360	449
	PHS1 = ABIP	450
	THS1 = 0.	451
	STEP = 1.	452
48	PH = PHS1-STEP	453
C	DO 51 K=1,NPHS	454
	PH = PH+STEP	455
	TH = THS1-STEP	456
	IF ((1/CRO.GT.0).AND.11TH.GT.90).AND.(TH.LT.270))) GO TO 51	457
C	DO 51 I=1,NTHS	458
	TH = TH+STEP	459
	L = L+1	460
	CALL GFFLO (1A,18,INC,INM,IWR,11,12,13,112,MO,N,NO,NM,AM,ACSP,ACST	461
	1,C,CGD,CG,CJ,CMM,O,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ETTS,GG,	462
	2CPP,GT1,PH,SGD,SCSP,SCST,SPPH,SPTH,STPH,STTM,TH,X,Y,Z,ZLO,ZS,ETA,G	463
	3AM,ERR,IGRO)	464
	IF (IWR.GT.0) GO TO 49	465
	IF (NPL.LT.0) WRITE (6,63) PH,TH,SPPH,SPTH,STPH,STTM	466
49	CPII(L) = PH	467
	CTHET(L) = TH	468
	COAT1(L) = EPPS	469
	COAT2(L) = EPTS	470
	COAT3(L) = ETPS	471
	COAT4(L) = ETTS	472
	IF (NPL.NE.1) GO TO 50	473
	DATY1(K) = CABS(EPPS)	474
		475
		476
		477
		478
		479
		480

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OATY2(K) = CABS(EPTS)
OATY3(K) = CABS(ETPS)
OATY4(K) = CABS(ETTS)
50 IF (NPL.NE.2) GO TO 51
OATY(1) = CABS(EPPS)
OATY2(1) = CABS(EPTS)
OATY3(1) = CABS(ETPS)
OATY4(1) = CABS(ETTS)
51 CONTINUE
C
WRITE (6,82)
IF (NPL.LE.0) GO TO 52
CALL POLPRT (3,OATY1)
CALL POLPRT (4,OATY2)
CALL POLPRT (5,OATY3)
CALL POLPRT (6,OATY4)
IF (KFLAG(18).NE.1) GO TO 54
52 WRITE (6,66)
C
OD 53 I=1,L
53 WRITE (6,65) CPH1(1),CTHET(1),COAT1(1),COAT2(1),COAT3(1),COAT4(1)
C
54 IF (IFLAG.EQ.1) GO TO 1
IF (IFLAG.EQ.2) STOP
C
OD 55 I=1,30
55 KFLAG(1) = -1
C
KFLAG(18) = 1
KFLAG(20) = 1
KFLAG(26) = 1
IF (IFLAG.EQ.3) WRITE (6,68)
IF (IFLAG.EQ.6) WRITE (6,115)
GO TO 4
C
56 FORMAT (1H0)
57 FORMAT (10X,'THE RADIATION EFFICIENCY IS ',F15.7//10X,'THE TIME-AV
ERAGE POWER INPUT IS ',F15.7//10X,'THE ANTENNA IMPEOANCE IS ',F15.
27,'+',J',F15.7//)
58 FORMAT (10X,'THE NEAR-FIELD ELECTRIC FIELD INTENSITY AT THE OBSERV
ATION POINT ',E11.5,'+',E11.5,'+',E11.5,' (X,Y,Z RESPECTIVELY) IS:
2//)
59 FORMAT (20X,'EX=',F15.7,'+',J',F15.7/20X,'EY=',F15.7,'+',J',F15.7/20
1X,'EZ=',F15.7,'+',J',F15.7//)
60 FORMAT (3X,F5.1,2X,F5.1,3X,E10.4,2X,E10.4,2X,F6.1,1X
1)
61 FORMAT (141,'FOR BISTATIC SCATTERING THE INCIDENT',/141,'PLANE WAVE
1 IS PH1=',F5.1,' THETA=',F5.1//)

62 FORMAT (1' INCIDENT',I27,'ECHO AREA SIGMA',I66,'ABSORPTION',I90,'EX
11 INCIUION',I114,'SCATTERING',/1' PLANE',I25,'(INCIDENT-SCATTERED)',I
24X,3(5X,'CROSS SECTION',6X)/' WAVE ',52X,3(10X,'FOR',11X)/' PH1
3 THETA',3X,'PH1-PH1',3X,'PH1-THETA',4X,'THETA-PH1',2X,'THETA-THETA
4',3(5X,'PH1',7X,'THETA',4X))
63 FORMAT (1X,2(F5.1,1X),10(E10.4,2X))
64 FORMAT (154,'BACKSCATTERING',/1' INCIDENT',I37,'ELECTRIC FIELD POLAR
1IZATION SCATTERING MATRIX',/1' PLANE',I49,'(INCIDENT-SCATTERED)',73X
2' WAVE',I23,'PH1-PH1',I49,'PH1-THETA',I75,'THETA-PH1',I102,'THETA-
3 THETA',/1' PH1 THETA',3X,4(3X,'REAL',RX,'IMAG',8X))
65 FORMAT (1X,2(F5.1,1X),12X,4(E11.5,2X,E11.5,3X))
66 FORMAT (154,'BISTATIC',I37,'ELECTRIC FIELD POLARIZATION SCATTERING
1 MATRIX',/1' OBSERVATION',I50,'(INCIDENT-SCATTERED)',/1' POINT',I4X,
2 'PH1-PH1',I49,'PH1-THETA',I75,'THETA-PH1',I101,'THETA-THETA',/1' P
3H1 THETA',4X,4(3X,'REAL',8X,'IMAG',8X))
67 FORMAT (1' OBSERVATION',I27,'ECHO AREA SIGMA',/1' POINT',I25,'(INCI
IDENT-SCATTERED)',/1' PH1 THETA',I14,'PH1-PH1',I24,'PH1-THETA',I37,
2 'THETA-PH1',I48,'THETA-THETA')
68 FORMAT (11H1,5X,'CONTINUE EXECUTION WITH THE FOLLOWING ADDITIONS AN
10/0R CHANGES'//)
69 FORMAT (54X,'ELECTRIC FIELD INTENSITY',/5X,'DEGREES',11X,'POWER GAI
IN',28X,'THETA',42X,'PH1',/3X,'THETA',3X,'PH1',7X,'THETA',8X,'PH1',1
2X,2(18X,'REAL',8X,'IMAG',8X,'MAGN',5X,'PHASE'))
70 FORMAT (10X,'*****ERROR IN DATA CARD NUMBER ',I2,' EXECUTION STOP
PED*****')
71 FORMAT (40X,' A WIRE SEGMENT MAYNOT BE SHARED BY MORE THAN FO
1UR ',/40X,' DIPOLE MODES-----CHECK DESCRIPTION DATA CA
2RD ',/40X,' EXECUTION STOPPED
3 ')
72 FORMAT (40X,' AN ISOLATED WIRE MUST HAVE AT LEAST TWO SEGMENT
1S ',/40X,' AND THREE POINTS---CHECK DESCRIPTION DATA CA
2RD ',/40X,' EXECUTION STOPPED
3 ')
73 FORMAT (30X,'A BACKSCATTERING CALL MUST BE INCLUDED FOR A BISTATIC
1 CALL',/50X,'REQUEST IGNORED',/11X)
74 FORMAT (1'1',I50,37(' ')/I50,'',I86,'')
1 I50,' OHIO STATE UNIVERSITY ''/
2 I50,' ANTENNA ANALYSIS PROGRAM ''/
3 I50,' MODIFIED FOR USE AT ''/
4 I50,' NAVAL POSTGRADUATE SCHOUL ''/
5 I50,' 17 JULY 1974 ''/
6 I50,'',I86,'',/I50,37(' ')/
75 FORMAT (1'1',I50,29(' ')/I50,'',I78,'')
76 FORMAT (I50,'',11X,'ANTENNA',I78,'')
77 FORMAT (I50,'',9X,'CALCULATIONS',I78,'',/I50,'',I78,'',/I50,29('
1 '))
78 FORMAT (I50,'',9X,'NEAR FIELD',I78,'')
79 FORMAT (I50,'',9X,'FAR FIELD',I78,'')

```



```

80 FORMAT (I50,'*',7X,'BACKSCATTERING',T78,'*')
81 FORMAT (I50,'*',4X,'BISTATIC SCATTERING',T78,'*')
82 FORMAT (////)
83 FORMAT (T30,'FREQUENCY (MHZ)',T81,E11.5)
84 FORMAT (T30,'WIRE RADIUS (METERS)',T81,E11.5)
85 FORMAT (T30,'WIRE CONDUCTIVITY (MEGAMHOS/METER)',T81,E11.5)
86 FORMAT (T30,'WIRE INSULATED (NU/YES)',T85,'YES')
87 FORMAT (T30,'WIRE INSULATED (NU/YES)',T85,'NO')
88 FORMAT (T30,'INSULATION RADIUS (METERS)',T81,E11.5)
89 FORMAT (T30,'INSULATION CONDUCTIVITY (MHOS/METER)',T81,E11.5)
90 FORMAT (T30,'INSULATION DIELECTRIC CONSTANT (RELATIVE)',T81,E11.5)
91 FORMAT (T30,'INSULATION LOSS TANGENT',T81,E11.5)
92 FORMAT (T30,'EXTERIOR MEDIUM',T81,'FREE SPACE')
93 FORMAT (T30,'EXTERIOR MEDIUM CONDUCTIVITY (MHOS/METER)',T81,E11.5)
94 FORMAT (T30,'EXTERIOR MEDIUM DIELECTRIC CONSTANT (RELATIVE)',T81,
  1'E11.5)
95 FORMAT (T30,'EXTERIOR MEDIUM LOSS TANGENT',T81,E11.5)
96 FORMAT (I50,'WIRE STRUCTURE'//T20,'SEG',4X,2('NODE',19X,'LOCATION',
  1,18X)/T21,'NU',3X,2('NU',9X,'X',13X,'Y',13X,'Z',7X)/T21,12,5X,
  22(12,5X,E11.5,4X,E11.5,4X,E11.5,1X)))
97 FORMAT (I50,'ANTENNA FEEDS'//T40,'NODE',16X,'VOLTS'//T41,'NO',12X,
  1'REAL',7X,'IMAGINARY'//T41,12,6X,2(4X,E11.5)))
98 FORMAT (I50,'*',6X,'OUTPUT REQUESTED',T78,'*')
99 FORMAT (T30,'STRUCTURE CURRENTS')
100 FORMAT (T30,'FAR FIELDS FOR PHI VARYING FROM',1X,F5.1,' TO ',F5.1,
  1' AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
  2150,'IN STEPS OF ',F5.1,' DEGREES.')
101 FORMAT (T30,'BACKSCATTERING FOR PHI VARYING FROM ',F5.1,' TO ',F5.
  11', AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
  2150,'IN STEPS OF ',F5.1,' DEGREES.')
102 FORMAT (T30,'BISTATIC SCATTERING FOR PHI VARYING FROM ',F5.1,' TO
  1',F5.1,' AND THETA VARYING FROM ',F5.1,' TO ',F5.1/
  2150,'IN STEPS OF ',F5.1,' DEGREES.')
103 FORMAT (T30,'NEAR FIELDS FOR FOLLOWING POINTS (X,Y,Z)'/50(140,3(1E1
  11.5,5X)))
104 FORMAT (T30,'PLOT FOR FAR FIELD THETA=',F5.1)
105 FORMAT (T30,'PLOT FOR FAR FIELD PHI=',F5.1)
106 FORMAT (T30,'PLOT FOR BISTATIC SCATTERING FOR THETA=',F5.1)
107 FORMAT (T30,'PLOT FOR BISTATIC SCATTERING FOR PHI=',F5.1)
108 FORMAT (T30,'PLOT FOR BACKSCATTERING THETA=',F5.1)
109 FORMAT (T30,'PLOT FOR BACKSCATTERING PHI=',F5.1)
110 FORMAT (T30,'NO OUTPUT OR PLOTS REQUESTED')
111 FORMAT (//)
112 FORMAT (I50,'*',T78,'*'/T50,29('**'))
113 FORMAT (I50,'*',8X,'INPUT DATA ',T78,'*')
114 FORMAT (I50,29('**')/T50,'*',T78,'*')
115 FORMAT (10X,'SINCE THIS DATA BLOCK DOES NOT HAVE A TERMINATION CAR
  10 A CHANGE CARD IS ASSUMED')

116 FORMAT (//10X,40('**')/10X,'THE DESCRIPTION AND THE GEOMETRY OF THE
  1 STRUCTURE'//10X,'MUST BE STATED IN THE FIRST DATA BLOCK.'//10X,'**
  2* EXECUTION STOPPED ***')
117 FORMAT (//10X,'NO PART OF THE WIRE STRUCTURE CAN LIE BELOW THE GRO
  1 UND PLANE.'//10X,'***EXECUTION STOPPED***')
118 FORMAT (I50,'STRUCTURE LOADS'//T40,'NODE',16X,'OHMS'//T41,'NO',12X
  1'REAL',7X,'IMAGINARY'//T41,12,6X,2(4X,E11.5)))
119 FORMAT (I50,'STRUCTURE LOADS'//T39,'SEGMENT',14X,'OHMS'//T41,'NO',12
  1X,'REAL',7X,'IMAGINARY'//T41,12,6X,2(4X,E11.5)))
120 FORMAT (I50,'ANTENNA FEEDS'//T39,'SEGMENT',14X,'VOLTS'//T41,'NO',12
  1X,'REAL',7X,'IMAGINARY'//T41,12,6X,2(4X,E11.5)))
121 FORMAT (//T30,'THE NUMBER OF INTERVALS FOR CALCULATING THE ELEMENT
  1S'//T30,13,' IF CLOSED FORM INTEGRATION IS REQUIRED SET INT=0'//)
2,T30,13,' IF CLOSED FORM INTEGRATION IS REQUIRED SET INT=0'//)
122 FORMAT (T30,'GROUND PLANE (NU/YES)',T85,'NO')
123 FORMAT (T30,'GROUND PLANE (NU/YES)',T85,'YES')
124 FORMAT (T30,'GROUND DIELECTRIC CONSTANT (RELATIVE)',T81,E11.5/
  1T30,'GROUND CONDUCTIVITY (MHOS/METER)',T81,E11.5)
125 FORMAT (T30,'GROUND PLANE',T83,'PERFECT')
126 FORMAT (T30,'ANTENNA HEIGHT (METERS)',T81,E11.5)
127 FORMAT (//10X,40('**')/10X,'THE WIRE RADIUS MUST BE STATED'//10X,40(
  1'**'))
  ENO

```

BLNK

PURPOSE: to compress data to the left by removal of
the blank spaces on the input data cards.

METHOD: A(I) character is compared to the blank; and
if it is true, the A(I+1) character is shifted to the A(I)
position.

CALLED BY: READ

CALLS TO: NONE

```

SUBROUTINE BLNK (A)
  DIMENSION A(80)
  DATA BLANK/' '/
  K = 0
C
  DO 1 I=1,80
    J = I-K
    A(J) = A(I)
  1 IF (A(I).EQ.BLANK) K=K+1
C
  IF (K.EQ.0) RETURN
  A(81-K) = BLANK
  RETURN
END
```

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CBES

PURPOSE: to calculate the quantity B01 where

$$B01 = J_0(z) / J_1(z).$$

METHOD: If the absolute value of the argument for the Bessel function is less than 12, B01 is calculated via the power series expansion for the Bessel function in the DO LOOP ending at statement 3. If greater than 12, the asymptotic expression is utilized at statement 4. If the magnitude of the complex part of the argument for the Bessel function is greater than 20, B01 is set to (0.,-1). If the complex part of the argument is negative, the sign of B01 is changed prior to returning to the calling program.

CALLED BY: SGANT

CALLS TO: NONE

```

SUBROUTINE CBES (Z,B01)
  COMPLEX ARG,CC,CS,EX
  COMPLEX B01,Z,TERMJ,TERMN,MZ24,JN(2)
  DATA PI/3.14159/
  IF (CABS(Z).GE.12.0) GO TO 4
  FACTOR = 0.0
  TERMN = 10.0
  MZ24 = -0.25*Z*Z
  TERMJ = 11.0,0.0)
C
  DO 3 NP=1,2
    N = NP-1
    JN(NP) = TERMJ
    M = 0
  1 M = M+1
    TERMJ = TERMJ*MZ24/FLOAT(M*N*M)
    JN(NP) = JN(NP)+TERMJ
    IF (NP.NE.1) GO TO 2
    FACTOR = FACTOR+.0/FLOAT(M)
    TERMN = TERMN+TERMJ*FACTOR
  2 ERROR = CABS(TERMJ)
    IF (ERROR.GT.1.0E-10) GO TO 1
  3 TERMJ = 0.5*Z
C
  B01 = JN(1)/JN(2)
  RETURN
  4 Y = AIMAG(Z)
    IF (ABS(Y).GT.20.) GO TO 5
    ARG = 1.0,1.)*Z
    EX = CEXP(ARG)
    CC = EX+./EX
    CS = 1.0,-1.)*(EX-1./EX)
    B01 = (CS*CC)/(CS-CC)
    RETURN
  5 B01 = 1.0,-1.)
    IF (Y.LT.0.) B01 = 1.0,1.)
    RETURN
  ENO

```

DSHELL

PURPOSE: to calculate the mutual impedance term contributed by the dielectric insulation on the surface of a thin wire.

METHOD: The contribution to the impedance matrix is calculated utilizing the equation below

$$z_{mn} = - \frac{(\epsilon_2 - \epsilon) \ln(b/a)}{2\pi j\omega\epsilon\epsilon_2} \int_{m,n} F'_m(l) F'_n(l) dl ,$$

where z_{mn} is defined in subroutine SGANT, ϵ_2 is the dielectric constant of the insulation, b is the outer radius of the insulation, a is the inner radius, ϵ is dielectric constant of the external medium, and F is the sinusoidal expansion function.

CALLED BY: SGANT

CALLS TO: NONE

```
SUBROUTINE DSHELL (AM,BM,OK,CGDS,SGDS,EP2,EP,ETA,GAM,P11,P12)
COMPLEX CGDS,SGDS,EP2,EP,ETA,GAM,P11,P12,GO,CST
DATA PI/3.14159/
GO = GAM*OK
CST = (EP2-EP)*ETA*ALOG(BM/AM)/(4.*PI*EP2*SGDS*SGDS)
P11 = -CST*(GO*SGDS*CGDS)
P12 = CST*(GO*CGDS*SGDS)
RETURN
END
```

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EQUAL

PURPOSE: to determine position (location) of the equal symbol on input data card.

METHOD: The character search begins in the column passed to the subroutine. On returning to the calling program, the argument passed is the column following the equal symbol.

CALLED BY: READ

CALLS TO: NONE

```

SUBROUTINE EQUAL (N)
COMMON /A/ A(80)
DATA EQUAL/'='/'
K = N
C DO 1 I=K,80
  N = I+1
  IF (A(I)).EQ.EQUAL) GO TO 2
1 CONTINUE
C N = 1
2 RETURN
END
```

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EXPJ

PURPOSE: to calculate the exponential integral with complex limits.

METHOD: The exponential integral is defined as:

$$W12 = \int_{V1}^{V2} \frac{e^{-v}}{v} dv = E_1(V1) - E_1(V2) + j2nn ,$$

where the integration path is the straight line from V1 to V2 on the complex v plane and

$$E_1(z) = \int_z^{\infty} \frac{e^{-t}}{t} dt .$$

The integration path is a horizontal line in the w plane or an inclined straight line from V1 to V2 the v plane. The integer n is zero unless this path intersects the negative real v axis at a point between V1 and V2. When there is such an intersection,

a) $n = 1$ if $\text{Im}(V1) > \text{Im}(V2)$

b) $n = -1$ if $\text{Im}(V1) < \text{Im}(V2)$.

The term $j2nn$ is calculated below statement 12.

CALLED BY: GGMM

CALLS TO: NONE

```

SUBROUTINE EXPJ (V1,V2,W12)
COMPLEX FC,E15,S,T,UC,VC,V1,V2,W12,Z
OIMFNSION V(2), W(2), U(16), E(16)
DATA V/0.2278466E00,0.11889321E01,0.29927363E01,0.57751436E01,0.9
18374674E01,0.15982874E02,0.93307812E-01,0.49269175E00,0.12155954E0
21,0.22699495E01,0.36676227E01,0.54253366E01,0.75659162E01,0.101202
328E02,0.13130232E02,0.16654408E02,0.20776479E02,0.25623894E02,0.31
4407517E02,0.38530683E02,0.48026086E02/
DATA W/0.45896460E00,0.41700083E00,0.11337338E00,0.10399197E-01,0.
12610172E-03,0.89854791E-06,0.21823487E00,0.34221017E00,0.26302758
2E00,0.12642582E00,0.40206865E-01,0.85638778E-02,0.12124361E-02,0.1
31167440E-03,0.64599267E-05,0.22263169E-06,0.42274304E-08,0.3921897
43E-10,0.14565152E-12,0.14830270E-15,0.16005949E-19/
DATA O/0.22495842E02,0.74411568E02,-0.41431576E03,-0.78754339E02,0
1.11254744E02,0.16021761E03,-0.23862195E03,-0.50094687E03,-0.684878
254E02,0.12254778E02,-0.10161976E02,-0.47219591E01,0.79729681E01,-0
3.21069574E02,0.22046490E01,0.89728244E01/
DATA E/0.21103107E02,-0.31959787E03,-0.97489220E02,0.12900672E03,0
1.17949226E02,-0.12910931E03,-0.55705574E03,0.13524801E02,0.1469672
11E03,0.17949528E02,-0.32981014E00,0.31028836E02,0.81657657E01,0.22
3236961E02,0.39124892E02,0.81636799E01/
Z = V1
C
DO (2 J1M=1,2
X = REAL(Z)
Y = AIMAG(Z)
E15 = (0.,0)
A8 = CABS(Z)
IF (A8.EQ.0.) GO TO 11
IF (X.GE.0..AND.A8.GT.10.) GO TO 10
YA = ABS(Y)
IF (X.LE.0..AND.YA.GT.10.) GO TO 10
IF (YA-X.GE.17.5.OR.YA.GE.6.5.OR.X+YA.GE.5.5.OR.X.GE.3.) GO TO 2
IF (X.LE.-9.1) GO TO 6
IF (YA-X.GE.2.5) GO TO 7
IF (X+YA.GE.1.5) GO TO 3
N = 6.+3.*A8
E15 = 1./(N-1.)-Z/N**2
1 N = N-1
E15 = 1./(N-1.)-Z*E15/N
IF (N.GE.3) GO TO 1
E15 = Z*E15-CMPLX(1.577216*ALOG(A8),ATAN2(Y,X11
GO TO 11
2 J1 = 1
J2 = 6
GO TO 4
3 J1 = 7
J2 = 21
4 S = (0.,0)
YS = Y*Y
C
DO 5 (J1,J2
X1 = V(1)+X
CF = W(1)/(X1*X(1)+YS)
5 S = S+CMPLX(X1*CF,-YA*CF)
C
GO TO 9
6 T3 = X*X-Y*Y
T4 = 2.*X*YA
T5 = X*T3-YA*T4
T6 = X*T4+YA*T3
UC = CMPLX(D(11)+D(12)*X+D(13)*T3+T5-E(12)*YA-E(13)*T4,E(11)+E(12)
1*X+E(13)*T3+T6+D(12)*YA+D(13)*T4)
VC = CMPLX(D(14)+D(15)*X+D(16)*T3+T5-E(15)*YA-E(16)*T4,E(14)+E(15)
1*X+E(16)*T3+T6+D(15)*YA+D(16)*T4)
GO TO 8
7 T3 = X*X-Y*Y
T4 = 2.*X*YA
T5 = X*T3-YA*T4
T6 = X*T4+YA*T3
T7 = X*T6-YA*T5
T8 = X*T6+YA*T5
T9 = X*T7-YA*T8
T10 = X*T8+YA*T7
UC = CMPLX(D(11)+D(12)*X+D(13)*T3+D(14)*T5+D(15)*T7+T9-E(2)*YA+E(3)*T4
1+E(4)*T6+E(5)*T8,E(11)+E(2)*X+E(3)*T3+E(4)*T5+E(5)*T7+T10+D(21)*YA
2+D(13)*T4+D(14)*T6+D(15)*T8)
VC = CMPLX(D(16)+D(17)*X+D(18)*T3+D(19)*T5+D(10)*T7+T9-E(7)*YA+E(8)*T
1+E(9)*T6+E(10)*T8,E(6)+E(7)*X+E(8)*T3+E(9)*T5+E(10)*T7+T10+D(7)
2*YA+D(18)*T4+D(19)*T6+D(10)*T8)
8 EC = UC/VC
S = EC/CMPLX(X,YA)
9 EX = EXP(-X)
T = EX*CMPLX(COS(YA),-S(N(YA)))
E15 = S*T
IF (Y.LT.0.) E15 = CONJG(E15)
GO TO 11
10 E15 = .409319/(Z+.193044)+.421831/(Z+1.02666)+.147126/(Z+.2.56788)+
1.206335E-7/(Z+.4.90035)+.107401E-2/(Z+.8.18215)+.158654E-4/(Z+12.734
22)+.317031E-7/(Z+.19.3957)
E15 = E15*CEXP(-Z)
11 IF (J1M.EQ.1) W12 = E15
12 Z = V2
C
Z = V2/V1
TH = ATAN2(A(MAG(Z),REAL(Z))-ATAN2(A(MAG(V2),REAL(V2))+ATAN2(AIMAG
1(V1),REAL(V1)))
AB = ABS(TH)
IF (AB.LT.1.1) TH = 0
IF (TH.GT.1.1) TH = 6.2831853
IF (TH.LT.-1.) TH = -6.2831853
W12 = W(2)-E15*CMPLX(0.,TH)
RETURN
END

```

GANT1

PURPOSE: to consider the wire structure as a transmitting antenna and calculate the input impedance and current distribution.

METHOD: If a wire antenna is driven by a voltage generator v_i located at one of the current sampling points l_i and if displacement currents are neglected, Ampere's law yields

$$V_m = v_i F_m(l_i)$$

where F is the sinusoidal expansion function. Thus, the excitation voltages V_m will vanish everywhere except where v_i is not zero.

The DO LOOP ending with statement 50 uses the delta-gap model defined above to determine the excitation voltage $CJ(I)$ for all the dipole modes. These are stored temporarily in $CG(I)$. Then subroutine $SQROT$ is called to obtain a solution of the simultaneous linear equations. $SQROT$ stores the solution (the loop currents) in $CJ(I)$.

In the DO LOOP ending at statement 80, the complex power input and input impedance(s) are calculated. The time-average power input (PIN) is the real part of the complex power input.

Subroutine $RITE$ is called to make the transformation from the loop currents to the branch currents. If IWR is a positive integer, $RITE$ will write out the list of branch currents.

GDISS

PURPOSE: to calculate the time-average power dissipated in the imperfectly conducting wire and in the lumped loads.

METHOD: The time-average power dissipated by the wire is calculated in the DO LOOP ending at statement 1 utilizing the equation below:

$$P_d = \frac{R_s}{2\pi a} \int_0^l I I^* dl$$

where R_s is the surface resistance of the wire and a is the radius of the wire.

The power dissipated by the lumped loads is calculated by the DO LOOP ending at statement 3. If the wire is perfectly conducting, $CMM < 0$, the first calculation is by-passed.

CALLED BY: GANT1

CALLS TO: NONE

	SUBROUTINE GDISS (AM,CG,CMH,D,DISS,GAM,NM,SGD,ZLD,ZS)	1
	COMPLEX CG(1),SGD(1),ZLD(1),CJA,CJB,GAM,ZS	2
	DIMENSION D(1)	3
	DATA PI/3.14159/	4
	DISS = .D	5
	IF (CMH.LE.D.) GO TO 2	6
	ALPH = REAL(GAM)	7
	BETA = AIMAG(GAM)	8
	RH = REAL(ZS)/(4.*PI*AM)	9
C	DO 1 K=1,NM	10
	DK = D(K)	11
	DEN = CABS(SGD(K))**2	12
	EAD = EXP(ALPH*DK)	13
	CAD = (EAD*1./EAD)/2.	14
	CBD = COS(BETA*DK)	15
	SAU = DK	16
	IF (ALPH.NE.D.) SAO=(EAD-1./EAD)/12.*ALPH	17
	SBD = DK	18
	IF (BETA.NE.D.) SBD=SIN(BETA*DK)/BETA	19
	FA = RH*(SAO*CAD-SBD*CBU)/DEN	20
	FB = 2.*RH*(CAD*SBD-SAO*CBU)/DEN	21
	CJA = CG(K)	22
	L = K+NM	23
	CJB = CG(L)	24
	1 DISS = DISS+FA*(CABS(CJA)**2+CABS(CJB)**2)+FB*(REAL(CJA)*REAL(CJB)	25
	+AIMAG(CJA)*AIMAG(CJB))	26
C		27
C	2 DO 3 J=1,NM	28
	K = J+NM	29
	3 DISS = DISS+REAL(ZLD(J))*(CABS(CG(J))**2)+REAL(ZLD(K))*CABS(CG(K)	30
	1)**2)	31
C		32
	RETURN	33
	END	34
		35
		36

GFF

PURPOSE: to calculate the far-zone field of a sinusoidal electric monopole.

METHOD: If an electric line source has length d and endpoints at (x_1, y_1, z_1) and (x_2, y_2, z_2) , then the coordinates of any point on the source are

$$x = x_1 + l \cos x$$

$$y = y_1 + l \cos y$$

$$z = z_1 + l \cos z$$

where $\cos x$, $\cos y$, $\cos z$ are the direction cosines of the l axis, and l is the distance along the source measured from the endpoint (x_1, y_1, z_1) . Let the current distribution on the monopole be

$$I(l) = \frac{I_1 \sinh \gamma(d-l) + I_2 \sinh \gamma l}{\sinh \gamma d}$$

where I_1 and I_2 are the endpoint currents. The far-zone field of this source is

$$E_\phi = (\cos x \cos \theta \cos \phi - \cos y \cos \theta \sin \phi + \cos z \sin \theta) E_1$$

$$E_\theta = (-\cos x \sin \phi + \cos y \cos \phi) E_1$$

where

$$E_1 = \frac{\eta e^{-\gamma r}}{4\pi r (1-g^2) \sinh \gamma d} \left[(e^{\gamma g d} - g \sinh \gamma d - \cosh \gamma d) I_1 e^{\gamma f(1)} + (e^{\gamma d} + g \sinh \gamma d - \cosh \gamma d) I_2 e^{\gamma f(2)} \right]$$

$$f(1) = x_1 \sin\theta \cos\phi + y_1 \sin\theta \sin\phi + z_1 \cos\theta$$

$$f(2) = x_2 \sin\theta \cos\phi + y_2 \sin\theta \sin\phi + z_2 \cos\theta$$

$$g = \cos x \sin\theta \cos\phi + \cos y \sin\theta \sin\phi + \cos z \cos\theta$$

and (r, θ, ϕ) are the spherical coordinates of the observation point.

In this subroutine the range dependence has been suppressed. The far field vanishes in the endfire direction where $GK = 0$. If a ground plane is present ($IGRD > 0$) the E_1 equation above is decomposed into the x , y , and z components and the reflection coefficients are applied before E_θ and E_ϕ field components are returned to the calling program.

CALLED BY: GFFLD

CALLS TO: NONE

SUBROUTINE GFF (XA,YA,ZA,XB,YB,ZB,D,CGD,SGD,CTH,STH,CPH,SPH,GAM,ET	1
1A,ET1,ET2,EP1,EP2,IGRD,ERR)	2
COMPLEX ERR,RV,RH,RR,EX,EY,EZ,EE	3
COMPLEX ET1,ET2,EP1,EP2,GAM,ETA	4
COMPLEX GD,CGD,SGD,EGD	5
COMPLEX EGFA,EGFB,EGGD,ESA,ESB	6
COMPLEX CST	7
FP = 12.56637	8
XAB = XB-XA	9
YAB = YB-YA	10
ZAB = ZB-ZA	11
CA = XAB/D	12
CB = YAB/D	13
CG = ZAB/D	14
G = (CA*CPH+CB*SPH)*STH+CG*CTH	15
GK = 1.-G*G	16
ET1 = (.0,.0)	17
ET2 = (.0,.0)	18
EP1 = (.0,.0)	19
EP2 = (.0,.0)	20
IF (GK.LT..001) GO TO 3	21
FA = (XA*CPH+YA*SPH)*STH+ZA*CTH	22
FB = (XB*CPH+YB*SPH)*STH+ZB*CTH	23
EGFA = CEXP(GAM*FA)	24
EGFB = CEXP(GAM*FB)	25
EGGD = CEXP(GAM*G*D)	26
CST = ETA/(GK*SGD*FP)	27
ESA = CST*EGFA*(EGGD-G*SGD-CGD)	28
ESB = CST*EGFB*(1./EGGD+G*SGD-CGD)	29
IF (IGRD.LE.0) GO TO 2	30
RV = (-1.,0)	31
RH = (-1.,0)	32
IF (IGRD.EQ.1) GO TO 1	33
RR = CSQRT(ERR-STH*STH)	34
RV = -(ERR*CTH-RR)/(ERR*CTH+RR)	35
RH = (CTH-RR)/(CTH+RR)	36
1 EX = CA*ESA	37
EY = CB*ESA	38
EZ = CG*ESA	39
EE = (EX*SPH-EY*CPH)*(RH-RV)	40
EX = EX*RV+EE*SPH	41
EY = EY*RV-EE*CPH	42
EZ = -EZ*RV	43
ESA = EX*CA+EY*CB+EZ*CG	44
EX = CA*ESB	45
EY = CB*ESB	46
EZ = CG*ESB	47
EE = (EX*SPH-EY*CPH)*(RH-RV)	48
EX = EX*RV+EE*SPH	49
EY = EY*RV-EE*CPH	50
EZ = -EZ*RV	51
ESB = EX*CA+EY*CB+EZ*CG	52
2 T = (CA*CPH+CB*SPH)*CTH-CG*STH	53
P = -CA*SPH+CB*CPH	54
ET1 = T*ESA	55
ET2 = T*ESB	56
EP1 = P*ESA	57
EP2 = P*ESB	58
3 CONTINUE	59
RETURN	60
END	61

GFFLD

PURPOSE: to calculate the far-field for the thin wire structure.

METHOD: The far-field for the structure is calculated from the loop currents. The loop currents are either the currents produced by the transmitting antenna calculations of subroutine GANT1 or the currents produced by an incident plane wave.

If the incident field is generated by a distance source with spherical coordinates (r_0, θ_0, ϕ_0) , the excitation voltages induced by a incident plane wave are

$$V_m = \int_m F_m E_i dl$$

where

$$E_i = E_0 \exp(\gamma \bar{r} \bar{r}_0) dl$$

where E_0 is a vector constant, $\bar{r}_0$ is a vector from the coordinate origin to the distance source, and $\bar{r}$ is the radial vector from the origin to the observation point.

The field E_m is generated by test dipole m when radiating in the homogeneous medium. Using the vector potential, the field at the distance point (r_0, θ_0, ϕ_0) is

$$E_m = - \frac{j\omega\mu e^{-\gamma r_0}}{4\pi r_0} \int_m F_m \exp(\gamma \bar{r} \bar{r}_0) dl$$

where the radial component is to be suppressed. From the above equations,

$$V_m = - \frac{4\pi r_0}{j\omega u} e^{j\gamma r_0} e_0 e_m .$$

If an antenna gain calculation is desired, INC is set to zero. PH and TH denote the spherical coordinate direction of the distance observation point. The phi-polarized (EPPS) and the theta-polarized (ETTS) components of the electric field intensity are returned to the calling program.

If INC = 1, a backscattering calculation is desired. In this case PH and TH denotes the incident angles for the incident plane wave. These are also the spherical coordinates of the distance source. The outputs returned to the calling program include absorption, extinction, and scattering cross section for each polarization; scattered electric field; and echo areas.

If INC = 2, a bistatic calculation is desired. In this case PH and TH denote the spherical coordinate of a distance observer. Since this calculation uses the induced loop currents (EP and ET), a backscattering call must precede this calculation. The outputs returned to the calling program consist of the scattered electric field components and echo areas.

EPP(I) and ETT(I) denote the phi-polarized and theta-polarized far-zone fields of dipole mode I with unit terminal current. In a backscattering situation, the excitation voltages EP(I) and ET(I) are obtained by multiplying EPP and ETT by the constant CJI. Then calls are made to SQROT which stores the solution (the induced loop currents) in EP(I) and ET(I). RITE is called for the branch

currents $CG(J)$, and $GDISS$ is called for the time-average power dissipated in the imperfectly conducting wire and the lumped loads. This power is denoted $PDISS$ and $TDISS$ for ϕ -polarized and θ -polarized incident waves, respectively.

In scattering problems, the incident plane wave has unit electric field intensity at the origin. GGG denotes the time-average power density of the incident wave at the origin. $ACSP$ and $ACST$ denote the absorption cross sections for the ϕ and θ polarizations.

PIN and TIN denote the time-average power input to the wire structure, delivered by the equivalent voltage generators VP and VT at the terminals. PIN and TIN apply for the ϕ and θ polarizations, respectively. The time-average power input is regarded as the sum of the time-average power dissipated and the time-average power radiated or scattered by the wire. $ECSP$ and $ECST$ denote the extinction cross sections and $SCSP$ and $SCST$ denote the scattering cross sections.

The distance field is calculated in the DO LOOP ending with statement 7 for scattering situations, and in the DO LOOP ending with statement 9 for the antenna situation.

The radar cross sections (echo areas) $SPPM$, $SPTM$, $STPM$, and $STTM$, are defined as

$$\sigma = \lim_{r \rightarrow \infty} 4\pi r^2 e^{2\alpha r} S_s / S_i$$

where S_s and S_i denote the time-average power densities in the scattered and incident fields evaluated at the origin.

For an antenna, the following definition is employed for

the power gains:

$$G_p(\theta, \phi) = \lim_r 4\pi r^2 e^{2ar} S(r, \theta, \phi) / P_i$$

where P_i , G_p , denote the time-average power input and

$S(r, \theta, \phi)$ is the time-average power density in the radiated field. G_{pp} and G_{tt} denote the power gains associated with the phi-polarized and the theta-polarized components of the field, respectively.

The use of the variables JFLAG and KFLAG are described in subroutine SGANT.

CALLED BY: MAIN

CALLS TO: GDISS

 GFF

 RITE

 SQROT

```

SUBROUTINE GFFLD (IA,IB,INC,INM,IWR,I1,I2,I3,I12,MO,N,ND,NM,AM,ACS
1P,ACST,C,CGO,CG,CJ,CMM,D,ECSP,ECST,EP,ET,EPP,ETT,EPPS,EPTS,ETPS,ET
2TS,G,GPP,GTT,PH,SGD,SCSP,SCST,SPPM,SPTM,STPH,STTH,TH,X,Y,Z,ZLO,ZS
3,ETA,GAM,ERR,IGRD)
CUMPLEX ERR
COMPLEX CJ1,ET1,ET2,EPI,EP2,EPPS,ETTS,EPTS,ETPS,ZS,VP,VT
COMPLEX C(I),CJ(I),EP(I),ET(I),EPP(I),ETT(I),ZLO(I)
COMPLEX ETA,GAM,CGO(I),SGD(I),CG(I)
DIMENSION IA(1),IB(1),I1(1),I2(1),I3(1),I12(1),MO(1),ND(1NM,4)
DIMENSION D(1),X(1),Y(1),Z(1)
DATA PI,TP/3.14159,6.28318/
CJ1 = -4.*PI/ETA*GAM
GGG = REAL(1./ETA)
THK = .0174533*TH
CTH = COS(THR)
STH = SIN(THR)
PHR = .0174533*PH
CPH = COS(PHR)
SPH = SIN(PHR)
C
DO 1 I=1,N
ETT(I) = (0.,0)
1 EPP(I) = (0.,0)
C
C
DO 3 K=1,NM
KA = IA(K)
KB = IB(K)
NGRD = IGRD
IF (K.LT.NM/2) IGRD=-1
CALL GFF (X(KA),Y(KA),Z(KA),X(KB),Y(KB),Z(KB),D(K),CGO(K),SGD(K),C
1TH,STH,CPH,SPH,GAM,ETA,ET),ET2,EPI,EP2,IGRD,ERR)
IGRD = NGRD
NDK = ND(K)
C
DO 3 I1=1,NOK
I = MO(K,I1)
FI = 1.
IF (KB.EQ.1211) GO TO 2
IF (KB.EQ.1111) FI=-1.
EPP(I) = EPP(I)+FI*EPI
ETT(I) = ETT(I)+FI*ET1
GO TO 3
2 IF (KA.EQ.1311) FI=-1.
EPP(I) = EPP(I)+FI*EP2
ETT(I) = ETT(I)+FI*ET2
3 CONTINUE
C
EPPS = (0.,0)
ETTS = (0.,0)
IF (INC.EQ.0) GO TO 8
IF (INC.EQ.2) GO TO 6
C
DO 4 I=1,N
ET(I) = ETT(I)*CJ1
4 EP(I) = EPP(I)*CJ1
C
CALL SQROT (C,EP,0,I12,N)
I12 = 2
CALL SQROT (C,ET,0,I12,N)
IF (IWR.GT.0) WRITE (6,10) PH,TH
IF (IWR.GT.0) WRITE (6,11)
CALL RITE (IA,IB,INM,IWR,I1,I2,I3,MO,ND,NM,EP,CG,IGRD)
CALL GDIS (AM,CG,CMM,D,PDIS,GAM,NM,SGD,ZLO,ZS)
IF (IWR.GT.0) WRITE (6,12)
CALL RITE (IA,IB,INM,IWR,I1,I2,I3,MO,ND,NM,ET,CG,IGRD)
CALL GDIS (AM,CG,CMM,D,TDIS,GAM,NM,SGD,ZLO,ZS)
ACSP = PDIS/GGG
ACST = TDIS/GGG
PIN = 0
TIN = 0
C
DO 5 I=1,N
VP = CJ1*EPP(I)
VT = CJ1*ETT(I)
PIN = PIN+REAL(VP*CONJG(EP(I)))
5 TIN = TIN+REAL(VT*CONJG(ET(I)))
C
ECSP = PIN/GGG
ECST = TIN/GGG
SCSP = ECSP-ACSP
SCST = ECST-ACST
6 EPTS = (0.,0)
ETPS = (0.,0)
C
DO 7 I=1,N
EPPS = EPPS+EP(I)*EPP(I)
EPTS = EPTS+EP(I)*ETT(I)
ETTS = ETT(I)*ETT(I)
7 ETPS = ETPS+ET(I)*EPP(I)
C
SPPM = 2.*TP*(CABS(EPPS)**2)
SPTM = 2.*TP*(CABS(EPTS)**2)
STPM = 2.*TP*(CABS(ETPS)**2)
STTH = 2.*TP*(CABS(ETTS)**2)
RETURN
C
8 DO 9 I=1,N
ETTS = ETTS+CJ1(I)*ETT(I)
9 EPPS = EPPS+CJ1(I)*EPP(I)
C
APP = CABS(EPPS)
ATT = CABS(ETTS)
GPP = 4.*PI*APP*APP*GGG/GG
GIT = 4.*PI*ATT*ATT*GGG/GG
RETURN
C
10 FORMAT 110X,'BRANCH CURRENTS ASSOCIATED WITH PLANE-WAVE SCATTERING
1 FOR THE INCIDENT ANGLES PH=',F5.1,' AND THETA=',F5.1//)
11 FORMAT 144X,'CURRENTS INDUCED BY THE PHI POLARIZED WAVE')
12 FORMAT 144X,'CURRENTS INDUCED BY THE THETA POLARIZED WAVE')
END

```

GGMM

PURPOSE: to calculate the mutual impedance between two filamentary monopoles with sinusoidal current distribution.

METHOD: As stated in subroutine SGANT, the mutual impedance of coupled dipoles may be expressed as sum of four monopole-monopole impedances. This subroutine calculates the mutual impedance with closed-form expressions in terms of exponential integrals.

For skew monopoles it can be shown that the monopole-monopole mutual impedance is given by:

$$z_{ij} = (-1)^{i+j} B \left[e^{tn} (F_{j1} - e^{-z_m} G_{12} + e^{z_m} G_{22}) - e^{-tn} (F_{j2} - e^{-z_m} G_{11} + e^{z_m} G_{21}) \right]$$

where $m = 2/i$, $n = 2/j$ and

$$B = \frac{\eta}{16 \pi \sinh d_1 \sinh d_2}.$$

The functions F_{ik} are defined by:

$$F_{ik} = 2 \sinh d_i e^{qz_i \cos \psi} E(R_i + qz_i \cos \psi - qt)$$

where $q = (-1)^k$, d_1 and d_2 are the lengths of the monopoles

being considered. The functions G_{ik} are defined as follows:

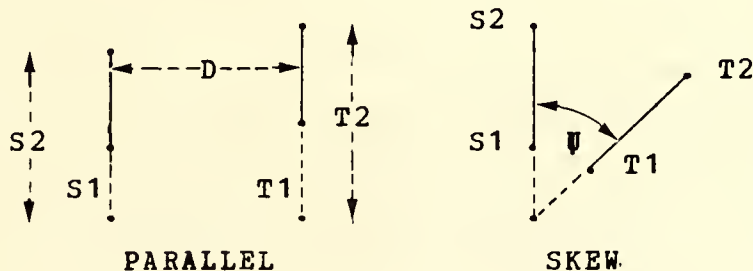
$$G_{ik} = E(R_2 + qz_2 + q't - jq'') + E(R_2 + qz_2 + q't + jq'') \\ - E(r_1 + qz_1 + q't - jq'') - E(R_1 + qz_1 + q't + jq'')$$

where $q = (-1)^i$, $q' = (-1)^k$, and $q'' = qb + q'c$ with $b = c \cos \Psi$ and $c = d/\sin \Psi$. The angle Ψ is the angle formed by the apparent intersection of the two monopoles. This will be discussed later in detail.

In the above equation for G^{ik} , t denotes the position of an observation point somewhere on monopole 2. R_1 and R_2 are the distances from the endpoints of monopole 1 to this observation point. Finally, the E functions are defined as follows:

$$E(a + jq'') = e^{jq''} \int_{a_1 + jq''}^{a_2 + jq''} \frac{e^{-\gamma w}}{w} dw$$

where a and q'' are real quantities with dimensions of length, a is a function of t , $a_1 = a(t_1)$, $a_2 = a(t_2)$ and $\gamma = jw\sqrt{\mu\epsilon}$. The integral above is evaluated by subroutine EXPJ.



To explain the input data for GGMM, refer to the above figure. If the monopoles are parallel, then the new coordinate system is defined such that the new z axis is parallel to the monopoles. The coordinate origin may be selected arbitrarily. $S1$ and $S2$ denote the z coordinates of

the endpoints of the test monopole, T1 and T2 are the coordinates of the endpoints of the expansion monopole, and D is the perpendicular distance (displacement) between the monopoles. The mutual impedance of parallel monopoles is calculated in the last part of GGMM below statement 5.

For skew monopoles, let the test monopole s lie in the xy plane and the expansion monopole t in the plane z = D. (D is the perpendicular distance between the parallel planes.) If the monopoles are viewed along a line of sight parallel with the z axis, the extended axes of the two monopoles will appear to intersect at a point on the xy plane. Let s measure the distance along the axis of the test monopole with the origin at the apparent intersection. S1 and S2 denote the s coordinates of the endpoints of the test monopole. Similarly, let t measure the distance along the axis of the expansion monopole with the origin at the apparent intersection. T1 and T2 denote the t coordinates of the endpoints of the expansion monopole. Let $\bar{s}$ and $\bar{t}$ be unit vectors parallel with the positive s and t axes, respectively. Then $\text{CPSI} = \bar{s} \cdot \bar{t} = \cos \psi$. The monopole lengths are d_s and d_t .

The output data from GGMM are the impedances P11, P12, P21, and P22. In defining these impedances, the reference direction is from S1 to S2 for the current on monopole s, and from T1 to T2 for the current on monopole t. In the impedance P_{ij} , the first subscript is 1 or 2 if the test dipole has terminals at S1 or S2 on monopole s. The second subscript is 1 or 2 if the expansion dipole has terminals at T1 or T2 on monopole t. The monopole lengths d_s and d_t are assumed positive in defining the input data CGDS, SGD1 and

SGD2.

For parallel monopoles, $CPSI = 1$ or -1 . $S1$, $S2$, $T1$, and $T2$ are cartesian coordinates for parallel monopoles and spherical coordinates for skew monopoles. For skew monopoles, the radial coordinates $S1$, $S2$, $T1$, and $T2$ tend to infinity as the angle Ψ tends to zero or π . Therefore, if the monopoles are within 4.5° of being parallel, they are approximated by parallel dipoles.

CALLED BY: GGS

SGANT

CALLS TO: EXPJ

```

SUBROUTINE GGMM (S1,S2,T1,T2,D,CGDS,SGD1,SGD2,CPSI,ETA,GAM,P11,P12
1,P21,P22)
1 DOUBLE PRECISION R1,R2,DPO,S1S,TS1,TS2,ST1,ST2,CD,BD,CPSS,SK,TL1,T
1L2,T01,T02,S01,DPSI,CD,ZO
COMPLEX CGDS,SGDS,SGD1,SGD2,ETA,GAM,P11,P12,P21,P22
COMPLEX CST,EB,EC,EK,EL,EKL,EGZ1,ES1,ES2,ET1,ET2,EXPA,EXPB
COMPLEX E1Z(2,2),F1Z(2,2)
COMPLEX EGZ(2,2),GM(2),GP(2)
DATA PI/3.14159/
DSQ = D*D
SGDS = SGD1
IF (S2.LT.S1) SGDS = -SGD1
SGDT = SGD2
IF (T2.LT.T1) SGDT = -SGD2
IF (ABS(CPSI).GT..997) GO TO 5
ES1 = CEXP(GAM*S1)
ES2 = CEXP(GAM*S2)
ET1 = CEXP(GAM*T1)
ET2 = CEXP(GAM*T2)
DO = D
DPSI = CPSI
T01 = T1
T02 = T2
CPSS = DPSI*DPSI
CD = DO/DSQRT(1.DO-CPSS)
C = CD
BD = CD*DPSI
B = BD
EB = CEXP(GAM*CMPLX(1.D,B))
EC = CEXP(GAM*CMPLX(1.D,C))
C DO I K=1,2
C DO I L=1,2
C 1 E(K,LI) = (1.D,.D)
TS1 = T01*T01
TS2 = T02*T02
DPO = DO*DO
S1 = S1
C DO I=1,2
FI = (-1)**I
S01 = S1
S1S = S01*S01
ST1 = 2.*S01*T01*DPSI
ST2 = 2.*S01*T02*DPSI
R1 = DSQRT(DPO*S1S+ST1-ST2)

```



```

RZ = DSQRT(DPQ+SLS+TS2-ST2)
EK = ER
C
DO 3 K=1,2
FK = 1-1)*K
SK = FK*SD1
EL = EC
C
DO 2 L=1,2
FL = (-1)*L
EKL = EK*EL
XX = FK*RD*FL*CD
TL1 = FL*TD1
TL2 = FL*TD2
RR1 = R1*SK*TL1
RR2 = R2*SK*TL2
CALL EXPJ (GAM*CMPLX(RR1,-XX),GAM*CMPLX(RR2,-XX),EXPA)
CALL EXPJ (GAM*CMPLX(RR1,XX),GAM*CMPLX(RR2,XX),EXPB)
E(K,L) = E(K,L)*F1*(EXPA*EKL+EXPB/EKL)
2 EL = 1./EC
C
3 EK = 1./EB
C
ZD = SD1*DPS1
ZC = ZD
EGZ1 = CEXP(GAM*ZC)
RR1 = R1*ZD-TD1
RR2 = R2*ZD-TD2
CALL EXPJ (GAM*RR1,GAM*RR2,EXPB)
RR1 = R1*ZD+TD1
RR2 = R2*ZD+TD2
CALL EXPJ (GAM*RR1,GAM*RR2,EXPA)
F(1,1) = 2.*SGDS*EXPA/EGZ1
F(1,2) = 2.*SGDS*EXPB/EGZ1
4 S1 = S2
C
CST = ETA/(16.*P1*SGDS*SGDT)
P11 = CST*((F(1,1)*E(2,2)*ES2-E(1,2)/ES2)*ET2+(F(1,2)-E(2,1)*ES2+
1E(1,1)/ES2)/ET2)
P12 = CST*((F(1,1)-F(1,1)*E(2,2)*ES2+E(1,2)/ES2)*ET1+(F(1,2)*E(2,1)*ES2-
1E(1,1)/ES2)/ET1)
P21 = CST*((F(1,2)-E(2,1)*ES1+E(1,2)/ES1)*ET2+(F(2,2)*E(2,1)*ES1-
1E(1,1)/ES1)/ET2)
P22 = CST*((F(2,1)*E(2,2)*ES1-E(1,2)/ES1)*ET1+(F(2,2)-E(2,1)*ES1+
1E(1,1)/ES1)/ET1)
RETURN
5 IF (CPS1.LT.0.) GO TO 6
TA = T1

```

```

TB = T2
GO TO 7
6 TA = -T1
TB = -T2
SGDT = -SGDT
7 S1 = S1
C
DO 9 I=1,2
TJ = TA
C
DO 8 J=1,2
Z1J = TJ-S1
R = SQRT(DSQ+Z1J*Z1J)
W = R*Z1J
IF (Z1J.LT.0.) W = OSQ/(R-Z1J)
V = R-Z1J
IF (Z1J.GT.0.) V = OSQ/(R+Z1J)
IF (J.EQ.1) V1 = V
IF (J.EQ.1) W1 = W
EGZ(1,J) = CEXP(GAM*Z1J)
8 TJ = TB
C
CALL EXPJ (GAM*V1,GAM*V,GP(1))
CALL EXPJ (GAM*W1,GAM*W,GM(1))
9 S1 = S2
C
CST = -ETA/(8.*P1*SGDS*SGDT)
P11 = CST*(GM(2)*EGZ(2,2)*GP(2)/EGZ(2,2)-CGDS*(GM(1)*EGZ(1,2)*GP(1
1)/EGZ(1,2)))
P12 = CST*(-GM(2)*EGZ(2,1)-GP(2)/EGZ(2,1)*CGDS*(GM(1)*EGZ(1,1)*GP(
1)/EGZ(1,1)))
P21 = CST*(GM(1)*EGZ(1,2)*GP(1)/EGZ(1,2)-CGDS*(GM(2)*EGZ(2,2)*GP(2
1)/EGZ(2,2)))
P22 = CST*(-GM(1)*EGZ(1,1)-GP(1)/EGZ(1,1)*CGDS*(GM(2)*EGZ(2,1)*GP(
1)/EGZ(2,1)))
RETURN
END

```

GGG

PURPOSE: to calculate the mutual impedances between two filamentary monopoles with sinusoidal current distributions.

METHOD: The monopole-monopole mutual impedance as defined by SGANT is calculated using the equations defined in subroutine GNF. The endpoints of the axial test monopole s are (X_A, Y_A, Z_A) and (X_B, Y_B, Z_B) , and the endpoints of the expansion monopole t are (X_1, Y_1, Z_1) and (X_2, Y_2, Z_2) . DS and DT denote the lengths of monopoles s and t , respectively, CAS , CBS and CGS are the direction cosines of monopole s , and CA , CB and CG are the direction cosines of monopole t .

The effects of ground for vertical co-linear monopoles are applied in a slightly different manner than mentioned previously. As with self impedance calculations, the test monopole and the expansion monopole are laterally displaced by the wire radius. This lateral displacement is used to determine the angle of incident. This technique is applied at statement 8.

If $INT = 0$, GGS calls GGMM for the closed form impedance calculations. Otherwise GGS calculates the mutual impedance via Simpson's-rule integration with the following number of sample points: $IP = INT + 1$. If the monopoles are parallel with small displacement, GGS calls GGMM to avoid the difficulties of numerical integration.

Since the point (X, Y, Z) of subroutine GNF lies on the expansion monopole t , T is the integration variable and is measured from (X_1, Y_1, Z_1) . C_1 is the current at T for the mode with terminals at (X_1, Y_1, Z_1) , and C_2 is the current at T for the mode with terminals at (X_2, Y_2, Z_2) . C denotes the Simpson's-rule weighting coefficient.

Below statement 7, GGS performs some analytic geometry in preparation for calling GGMM. The remainder of this section is concerned with this preparation.

Let $\vec{S}$ denote a unit vector in the direction from (X_A, Y_A, Z_A) toward (X_B, Y_B, Z_B) . Also let $\vec{T}$ denote a unit vector from (X_1, Y_1, Z_1) toward (X_2, Y_2, Z_2) . Then $\vec{S} \cdot \vec{T} = \cos \theta = CC$ where θ is the angle formed by the axes of the two monopoles. Let monopole s lie in one plane P_s and monopole t lie in another parallel plane P_t . CAD, CBD and CGD are the direction cosines of the unit vector $\vec{d} = \vec{T} \times \vec{S} / \sin \theta$ which is perpendicular to both planes. To obtain the distance DK between the two planes, a vector $\vec{R}_{11}$ is constructed from (X_A, Y_A, Z_A) to (X_1, Y_1, Z_1) and take $DK = \vec{R}_{11} \cdot \vec{d}$.

A line is constructed from (X_1, Y_1, Z_1) to the test monopole, such that the line is perpendicular to the test monopole. SZ denotes the s coordinate of the intersection of this line with the test monopole, and the cartesian coordinates of this intersection are XZ, YZ, and ZZ. The direction cosines of $\vec{S} \times \vec{d}$ are CAP, CBP, and CGP.

From the point (X_1, Y_1, Z_1) in plane P_t , a line is constructed perpendicular to the point (X_{P1}, Y_{P1}, Z_{P1}) in the

plane P_s . This line is parallel with $\vec{d}$ and has length DK .

Let $\vec{R}$ represent a vector from (XZ, YZ, ZZ) to $(XP1, YP1, ZP1)$.

$P1$ denotes $\vec{R} (\vec{S} \times \vec{d})$. $S1$ and $T1$ are defined in subroutine GGMM.

CALLED BY: SGANT

CALLS TO: GGMM

```

SUBROUTINE GGS (XA,YA,ZA,XB,YB,ZB,X1,Y1,Z1,X2,Y2,Z2,AM,DS,CGDS,SGD
1S,DT,SGD1,INT,ETA,GAM,P11,P12,P21,P22,EKR,IGRD)
COMPLEX EX1,EY1,EX2,EY2,EZ1,EZ2
COMPLEX P11,P12,P21,P22,EJA,EJB,EJ1,EJ2,ETA,GAM,C1,C2,CST
COMPLEX EGD,CGDS,SGDS,SGDT,ER1,ER2,ET1,ET2
COMPLEX ERK
COMPLEX EE,EXX,EYY
COMPLEX PP,PX,PY,PZ
COMPLEX RR1,RR2,RR3,RR4,RH1,RV1,RH2,RV2,RH3,RV3,RH4,RV4
DATA FP/12.56637/
CA = (X2-X1)/DT
CB = (Y2-Y1)/DT
CG = (Z2-Z1)/DT
CAS = (XB-XA)/DS
CBS = (YB-YA)/DS
CGS = (ZB-ZA)/DS
CC = CA*CAS+CB*CBS+CG*CGS
IF ((CG.LE..003).AND.(CGS.LE..003).AND.(IGRD.GT.0)) GO TO 1
IF (ABS(CC).GT..997) GO TO 6
1 SZ = (X1-XA)*CAS+(Y1-YA)*CBS+(Z1-ZA)*CGS
IF (INT.LE.0) GO TO 7
INS = 2*(INT/2)
IF (INS.LT.2) INS = 2
IP = INS+1
DELT = DT/INS
T = .0
DSZ = CC*DELT
P11 = (.0,.0)
P12 = (.0,.0)
P21 = (.0,.0)
P22 = (.0,.0)
AMS = AM*AM
SGN = -1.
C
C
DO 5 IN=1,IP
ZZ1 = SZ
ZZ2 = SZ-OS
XXZ = X1+T*CA-XA-SZ*CAS
YYZ = Y1+T*CB-YA-SZ*CBS
ZZZ = Z1+T*CG-ZA-SZ*CGS
RS = XXZ**2+YYZ**2+ZZZ**2
R1 = SQRT(RS+ZZ1**2)
EJA = CEXP(-GAM*R1)
EJ1 = EJA/R1
R2 = SQRT(RS+ZZ2**2)
EJB = CEXP(-GAM*R2)
EJ2 = EJB/R2

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ER1 = EJA*SGDS+ZZ1*EJ1*CGDS-ZZ2*EJ2
ER2 = -EJB*SGDS+ZZ2*EJ2*CGDS-ZZ1*EJ1
FAC = .0
IF (RS.GT.AMS1 FAC = (CA*XXZ+C8*YYZ+CG*ZZ)/RS
ET1 = CC*IEJ2-EJ1*CGDS)+FAC*ER1
ET2 = CC*IEJ1-EJ2*CGDS1+FAC*ER2
IF (IGRO.LT.0) GO TO 4
RV1 = (-1.,0)
RV2 = (-1.,0)
RH2 = (-1.,0)
IF (IGRO.EQ.1) GO TO 2
XG1 = X1+T*CA-XA
YG1 = Y1+T*CB-YA
ZG1 = Z1+T*CG-ZA
XG2 = X1+T*CA-XB
YG2 = Y1+T*CB-YB
ZG2 = Z1+T*CG-ZB
RG1 = SQRT(XG1*XG1+YG1*YG1)
RG2 = SQRT(XG2*XG2+YG2*YG2)
TT1 = ATAN(RG1/ZG1)
TT2 = ATAN(RG2/ZG2)
CTH1 = COS(TT1)
SSTH1 = SIN(TT1)*SIN(TT1)
CTH2 = COS(TT2)
SSTH2 = SIN(TT2)*SIN(TT2)
RR1 = CSORT(ERR-SSTH1)
RH1 = (CTH1-RR1)/(CTH1+RR1)
RV1 = -(ERR*CTH1-RR1)/(ERR*CTH1+RR1)
RR2 = CSORT(ERR-SSTH2)
RH2 = (CTH2-RR2)/(CTH2+RR2)
RV2 = -(ERR*CTH2-RR2)/(ERR*CTH2+RR2)
2 RG = SQRT((XB-XA)*(XB-XA)+(YB-YA)*(YB-YA))
CPH = 0
SPH = 0
IF (RG.LT.1.E-32) GO TO 3
CPH = (XB-XA)/RG
SPH = (YB-YA)/RG
3 EXX = ET1*CAS
EYY = ET1*CBS
EE = (EXX*SPH-EYY*CPH)*(RH1-RV1)
EX1 = EXX*RV1+EE*SPH
EY1 = EYY*RV1+EE*CPH
EZ1 = -ET1*RV1*CGS
ET1 = EX1*CAS+EY1*CBS+EZ1*CGS
EXX = ET2*CAS
EYY = ET2*CBS
EE = (EXX*SPH-EYY*CPH)*(RH2-RV2)

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EX2 = EXX*RV2+EE*SPH
EY2 = EYY*RV2+EE*CPH
EZ2 = -ET2*CGS*RV2
ET2 = EX2*CAS+EY2*CBS+EZ2*CGS
4 C = 3.*SGN
IF (JN.EQ.1.OR.IN.EQ.1P) C=1.
EGD = CEXP(GAM*DT-T)
C1 = C*(EGD-1./EGD)/2.
EGD = (EXP(GAM*T)
C2 = C*(EGD-1./EGD)/2.
P11 = P11+ET1*C1
P12 = P12+ET1*C2
P21 = P21+ET2*C1
P22 = P22+ET2*C2
T = T+DELT
SZ = SZ+DSZ
5 SGN = -SGN

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CST = -ETA*DELT/(3.*FP*SGDS*SGDT)
P11 = CST*P11
P12 = CST*P12
P21 = CST*P21
P22 = CST*P22
RETURN
6 SZ1 = (X1-XA)*CAS+(Y1-YA)*CBS+(Z1-ZA)*CGS
DR1 = SQRT((X1-XA-SZ1*CAS)**2+(Y1-YA-SZ1*CBS)**2+(Z1-ZA-SZ1*CGS)**2)
12) SZ2 = SZ1+DT*CC
DR2 = SQRT((X2-XA-SZ2*CAS)**2+(Y2-YA-SZ2*CBS)**2+(Z2-ZA-SZ2*CGS)**2)
12) DDD = (DR1+DR2)/2.
IF (DDD.GT.20.*AM.AND.INT.GT.0) GO TO 1
IF (DDD.LT.AM) DDD = AM
CALL GMM (.0,DS,SZ1,SZ2,DDD,CGDS,SGDS,SGDT,1.,ETA,GAM,P11,P12,P21)
1 P221
IF (IGRO.LE.0) RETURN
IF (IGRO.GT.1) GO TO 8
P11 = -P11
P12 = -P12
P21 = -P21
P22 = -P22
RETURN

```

C

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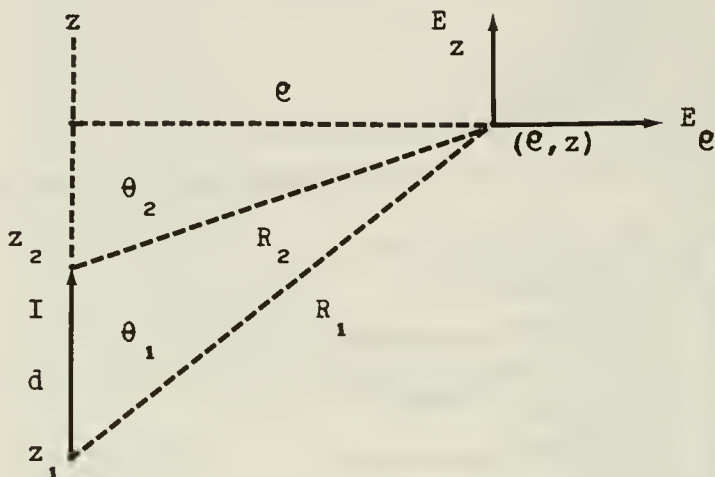
7 SS = SQRT(1.-CC*CC)
CAD = (CGS*CB-CBS*CG)/SS
C8D = (CAS*CG-CGS*CA)/SS
CGD = (CBS*CA-CAS*CB)/SS

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DK = (X1-XA)*CAO+(Y1-YA)*C8D+(Z1-ZA)*CGO	145
DK = ABS(DK)	146
IF (DK.LT.AM) DK = AM	147
XZ = XA+SZ*CA5	148
YZ = YA+SZ*CB5	149
ZZ = ZA+SZ*CG5	150
XP1 = X1-DK*CAO	151
YP1 = Y1-DK*C8D	152
ZP1 = Z1-DK*CGO	153
CAP = CB5*CGO-CG5*C8D	154
CBP = CG5*CAO-CA5*CGO	155
CGP = CA5*C8D-CB5*CAO	156
P1 = CAP*(XP1-XZ)+CBP*(YP1-YZ)+CGP*(ZP1-ZZ)	157
T1 = P1/SS	158
S1 = T1*CC-SZ	159
CALL GUMM (S1,S1+DS,T1,T1+DT,DK,CGDS,SGDS,SGDT,CC,ETA,GAM,P11,P12,	160
P21,P22)	161
RETURN	162
C	163
8 AMS = AM*AM	164
RG = (X1-XA)*(X1-XA)+(Y1-YA)*1Y1-YA)	165
IF (RG.LT.AMS) PG = AMS	166
UG = SQR11(Z1-ZA)*1Z1-ZA)+RG)	167
CPH = ABS(Z1-ZA)/DG	168
SSPH = RG/DG*DG	169
PR1 = CSQRT(ERR-SSPH)	170
RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)	171
P11 = P11*RV1	172
RG = (X1-XB)*(X1-XB)+1Y1-YB)*1Y1-YB)	173
IF (RG.LT.AMS) RG = AMS	174
UG = SQR11(Z1-ZB)*1Z1-ZB)+RG)	175
CPH = ABS(Z1-ZB)/DG	176
SSPH = RG/DG*DG	177
PR1 = CSQRT(ERR-SSPH)	178
RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)	179
P12 = P12*RV1	180
RG = (X2-XA)*(X2-XA)+(Y2-YA)*1Y2-YA)	181
IF (RG.LT.AMS) RG = AMS	182
DG = SQR11(Z2-ZA)*1Z2-ZA)+RG)	183
CPH = ABS1Z2-ZA)/DG	184
SSPH = RG/DG*DG	185
RR1 = CSQRT(ERR-SSPH)	186
RV1 = -(ERR*CPH-RR1)/(ERR*CPH+RR1)	187
P21 = P21*RV1	188
RG = 1X2-XB)*(X2-XB)+1Y2-YB)*1Y2-YB)	189
IF (RG.LT.AMS) RG = AMS	190
DG = SQR11(Z2-ZB)*1Z2-ZB)+RG)	191
CPH = ABS1Z2-ZB)/DG	192
SSPH = RG/DG*DG	193
RR1 = CSQRT(ERR-SSPH)	194
RV1 = -1ERR*CPH-RR1)/1ERR*CPH+RR1)	195
P22 = P22*RV1	196
RETURN	197
END	198

GNF

PURPOSE: to calculate the near-zone electric field of a sinusoidal electric monopole.



METHOD: An electric line source is located on the z axis with endpoints at z_1 and z_2 as shown in the above figure. Let the electric monopole have the following current distribution:

$$I(l) = \frac{I_1 \sinh \gamma(d - l) + I_2 \sinh \gamma l}{\sinh \gamma d}$$

where I_1 and I_2 are the endpoint currents, γ is the complex propagation constant of the medium, $d = z_2 - z_1$ is the source length. The cylindrical components of the field are $E(\theta) = 0$ and

$$E(e) = \frac{\eta}{4\pi e \sinh \gamma d} \left[(I_1 e^{-\gamma R_1} - I_2 e^{-\gamma R_2}) \sinh \gamma d \right. \\ \left. + (I_1 \cosh \gamma d - I_2) e^{-\gamma R_1} \cos \theta_1 \right. \\ \left. + (I_2 \cosh \gamma d - I_1) e^{-\gamma R_2} \cos \theta_2 \right]$$

$$E(z) = \frac{\eta}{4\pi \sinh \gamma d} \left[(I_1 - I_2 \cosh \gamma d) e^{-\gamma R_2} + (I_2 - I_1 \cosh \gamma d) e^{-\gamma R_1} \right]$$

where η is the intrinsic impedance of the medium and where (ρ, ϕ, z) denote the cylindrical coordinates in a coordinate system centered at the endpoint of z_1 .

These expressions exclude the field contributions from the point charges at the endpoints of the line source, since these charges disappear when two monopoles are connected to form a dipole.

Let the coordinate s measure distance along the test monopole with the origin at (X_A, Y_A, Z_A) . From any point X, Y, Z , a line is constructed perpendicular to the monopole. SZ denotes the s coordinate of the intersection of this line with the monopole. The length of the line is the radial coordinate ρ , and RS denote ρ^2 . R_1 and R_2 are the distances from (X_A, Y_A, Z_A) and (X_B, Y_B, Z_B) to the point (X, Y, Z) .

In the statements above statement 1, the above equations are solved; and after statement 1, the cartesian components (E_x, E_y, E_z) of the field are determined. If a ground plane is present ($IGRD > 0$) the reflection coefficients are applied to the cartesian components before returning to the calling program.

CALLED BY: GNFLD

CALLS TO: NONE

```

SUBROUTINE GNF (XA,YA,ZA,XB,YB,ZB,X,Y,Z,AM,OS,CGOS,SGOS,ETA,GAM,EX
1  I,EY1,EZ1,EX2,EY2,EZ2,IGRO,ERR)
2  CCMPLX ERR,RV1,RH1,RV2,RH2,RR1,RR2,EE
3  CCMPLX EJA,EJB,EJ1,EJ2,ER1,ER2,ES1,ES2,SGOS,GAM,CST,CGOS,ETA
4  CCMPLX EX1,EY1,EZ1,EX2,EY2,EZ2
5  DATA P1/3.14159/
6  CAS = (XB-XA)/OS
7  CBS = (YB-YA)/OS
8  CGS = (ZB-ZA)/OS
9  SZ = (X-XA)*CAS+(Y-YA)*CBS+(Z-ZA)*CGS
10 ZZ1 = SZ
11 ZZ2 = SZ-OS
12 XXZ = X-XA-SZ*CAS
13 YYZ = Y-YA-SZ*CBS
14 ZZZ = Z-ZA-SZ*CGS
15 RS = XXZ**2+YYZ**2+ZZZ**2
16 R1 = SQRT(RS+ZZ1**2)
17 EJA = CEXP(-GAM*R1)
18 EJ1 = EJA/P1
19 R2 = SQRT(RS+ZZ2**2)
20 EJB = CEXP(-GAM*R2)
21 EJ2 = EJB/R2
22 ES1 = EJ2-EJ1*CGOS
23 ES2 = EJ1-EJ2*CGOS
24 ER1 = (.0,.0)
25 ER2 = (.0,.0)
26 AMS = AM*AM
27 IF (RS.LT.AMS) GO TO 1
28 CTH1 = ZZ1/R1
29 CTH2 = ZZ2/R2
30 ER1 = (EJA*SGOS+EJA*CGOS*CTH1-EJB*CTH2)/RS
31 ER2 = (-EJB*SGOS+EJB*CGOS*CTH2-EJA*CTH1)/RS
32 CST = ETA/(4.*P1*SGOS)
33 EX1 = CST*(ES1*CAS+ER1*XXZ)
34 EY1 = CST*(ES1*CBS+ER1*YYZ)
35 EZ1 = CST*(ES1*CGS+ER1*ZZZ)
36 EX2 = CST*(ES2*CAS+ER2*XXZ)
37 EY2 = CST*(ES2*CBS+ER2*YYZ)
38 EZ2 = CST*(ES2*CGS+ER2*ZZZ)
39 IF (IGRO.LE.0) RETURN
40 RV1 = (-1,.0)
41 RH1 = (-1,.0)
42 RV2 = (-1,.0)
43 RH2 = (-1,.0)
44 IF (IGRO.EQ.1) GO TO 2
45 R1 = SQRT((XA-X)*(XA-X)+(YA-Y)*(YA-Y))
46 R2 = SQRT((XB-X)*(XB-X)+(YB-Y)*(YB-Y))
47 TH1 = ATAN(R1/(ZA-Z1))
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49 TH2 = ATAN(R2/(ZB-Z1))
50 RR1 = CSQRT(ERR-SIN(TH1)*SIN(TH1))
51 RR2 = CSQRT(ERR-SIN(TH2)*SIN(TH2))
52 RV1 = -(ERR*COS(TH1)-RR1)/(ERR*COS(TH1)+RR1)
53 RH1 = (COS(TH1)-RR1)/(COS(TH1)+RR1)
54 RV2 = -(ERR*COS(TH2)-RR2)/(ERR*COS(TH2)+RR2)
55 RH2 = (COS(TH2)-RR2)/(COS(TH2)+RR2)
56 RG = SQRT((XA-XB)*(XA-XB)+(YA-YB)*(YA-YB))
57 CPH = 0
58 SPH = 0
59 IF (RG.LT.1.E-32) GO TO 3
60 CPH = (XB-XA)/RG
61 SPH = (YB-YA)/RG
62 EE = (EX1*SPH-EY1*CPH)*(RH1-RV1)
63 EX1 = EX1*RV1+EE*SPH
64 EY1 = EY1*RV1-EE*CPH
65 EZ1 = EZ1*(-RV1)
66 EE = (EX2*SPH-EY2*CPH)*(RH2-RV2)
67 EX2 = EX2*RV2+EE*SPH
68 EY2 = EY2*RV2-EE*CPH
69 EZ2 = EZ2*(-RV2)
70 RETURN
71 ENO

```

GNFLD

PURPOSE: to calculate the near-zone electric field intensity at a given point.

METHOD: This subroutine calls GNF for the near-zone field of each wire segment, and sums over all segments to obtain the near-zone field of the wire antenna. FI is used in a manner similiar to FI of subroutine SGANT. CJ(I) is the loop currents calculated by subroutine GANT1.

The use of the variables JFLAG and KFLAG are described in subroutine SGANT.

CALLED BY: MAIN

CALLS TO: GPF

```

SUBROUTINE GNFLD (IA,IB,INM,11,12,13,MD,N,NO,NM,AM,CGO,SGO,ETA,GAM
1,CJ,D,X,Y,Z,XP,YP,ZP,EX,EY,EZ,IGRD,ERR)
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DO 2 K=(1,NM
KA = IA(K)
KB = IB(K)
NGRD = IGRD
IF (K.LT.NM/2) IGRD=-1
CALL GNF (X(KA),Y(KA),Z(KA),X(KB),Y(KB),Z(KB),XP,YP,ZP,AM,D(K),CGO
1(K),SGO(K),ETA,GAM,EX1,EY1,EZ1,EX2,EY2,EZ2,IGRD,ERR)
IGRD = NGRD
NOK = NO(K)
C
DO 2 I=(1,NOK
I = MO(K,I)
FI = 1.
IF (KB.EQ.12(1)) GO TO 1
IF (KB.EQ.11(1)) FI=-1.
EX = EX+FI*EX1*CJ(1)
EY = EY+FI*EY1*CJ(1)
EZ = EZ+FI*EZ1*CJ(1)
GO TO 2
1 IF (KA.EQ.13(1)) FI=-1.
EX = EX+FI*EX2*CJ(1)
EY = EY+FI*EY2*CJ(1)
EZ = EZ+FI*EZ2*CJ(1)
2 CONTINUE
C
RETURN
END

```

LEFT

PURPOSE: to determine position (location) of the left paren symbol on the input data card.

METHOD: The character search begins in the column passed to the subroutine. On returning to the calling program the argument passed is the column following the left paren symbol.

CALLED BY: READ

CALLS TO: NONE

```

SUBROUTINE LEFT (N)
COMMON /A/ A(80)
DATA PLEFT/'('/
K = N
C   DO 1 I=K,80
    N = I+1
    IF (A(I).EQ.PLEFT) GO TO 2
1  CONTINUE
C   N = I
2  RETURN
END
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LINECK

PURPOSE: to insert grid characters on the polar plot.

METHOD: The peroid character (ISM(2)) is inserted in the proper position in the statements above statement 4. In the statements after statement 4, the grid numbers labels are inserted on the horizontal axis.

CALLED BY: POLPLOT

CALLS TO: NONE

```

SUBROUTINE LINECK (X,Y)
C THIS SUBROUTINE INSURES ALL GRID CHARACTORS LIE ON THE POLAR GRID
C
COMMON ISYM,LINE
INTEGER Y
DIMENSION ISYM(14), LINE(130)
IF (Y.EQ.0) GO TO 3
K = 0
IF (X.LT.10.0) GO TO 5
C SET UP AREAS OF "PERIOD" POLAR GRID POINT CHARACTERS
C
1 = INT(X)
I = 1ABS(I)
Z = ABS(X)
IF ((Z-1).GT.0.5) I=I+1
1 IF (Z.LT.10.0.AND.Z.GT.111.0) GO TO 2
LINE(1) = ISYM(2)
LINE(60) = ISYM(3)
LINE(62) = ISYM(3)
K = K+1
IF (K.EQ.2) GO TO 2
I = 122-I
GO TO 1
2 LINE(61) = ISYM(2)
IF (Y.NE.0) GO TO 5
C
3 DO 4 K=1,111
LINE(K) = ISYM(2)
4 CONTINUE
C
C FILL IN GRID NUMBER LABELS ON HORIZONTAL AXIS
C
LINE(11) = ISYM(7)
LINE(20) = ISYM(10)
LINE(21) = ISYM(5)
LINE(22) = ISYM(11)
LINE(30) = ISYM(9)
LINE(31) = ISYM(5)
LINE(32) = ISYM(11)
LINE(40) = ISYM(8)
LINE(41) = ISYM(5)
LINE(42) = ISYM(11)
LINE(50) = ISYM(7)
LINE(51) = ISYM(5)
LINE(52) = ISYM(11)

LINE(61) = ISYM(1)
LINE(70) = ISYM(7)
LINE(71) = ISYM(5)
LINE(72) = ISYM(11)
LINE(80) = ISYM(8)
LINE(81) = ISYM(5)
LINE(82) = ISYM(11)
LINE(90) = ISYM(9)
LINE(91) = ISYM(5)
LINE(92) = ISYM(11)
LINE(100) = ISYM(10)
LINE(101) = ISYM(5)
LINE(102) = ISYM(11)
LINE(111) = ISYM(7)
5 CONTINUE
RETURN
END

```

NUMB

PURPOSE: to place degree numbers on the polar plot.

METHOD: The current line which is being printed is passed to the subroutine in the calling argument. If this line contains degree numbers, these numbers are placed in the correct position by the IF statements.

CALLED BY: PTPLOT

CALLS TO: NONE

```

C      SUBROUTINE NUMB (Y)
C      THIS SUBROUTINE PUTS DEGREE NUMBERS ON POLAR GRID
C
COMMON /SYM,LINE
INTEGER Y
DIMENSION /SYM(14), LINE(130)
IF (Y.NE.37) GO TO 1
LINE(33) = /SYM(7)
LINE(34) = /SYM(8)
LINE(35) = /SYM(6)
LINE(87) = /SYM(6)
LINE(88) = /SYM(12)
LINE(89) = /SYM(6)
1 IF (Y.NE.21) GO TO 2
LINE(12) = /SYM(7)
LINE(13) = /SYM(11)
LINE(14) = /SYM(6)
LINE(108) = /SYM(6)
LINE(109) = /SYM(9)
LINE(110) = /SYM(6)
2 IF (Y.NE.0) GO TO 3
LINE(7) = /SYM(7)
LINE(8) = /SYM(13)
LINE(9) = /SYM(6)
LINE(113) = /SYM(6)
LINE(114) = /SYM(6)
LINE(115) = /SYM(6)
3 IF (Y.NE.-21) GO TO 4
LINE(12) = /SYM(8)
LINE(13) = /SYM(7)
LINE(14) = /SYM(6)
LINE(108) = /SYM(9)
LINE(109) = /SYM(9)
LINE(110) = /SYM(6)
4 IF (Y.NE.-37) GO TO 5
LINE(33) = /SYM(8)
LINE(34) = /SYM(10)
LINE(35) = /SYM(6)
LINE(87) = /SYM(9)
LINE(88) = /SYM(6)
LINE(89) = /SYM(6)
5 CONTINUE
RETURN
END
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NUMBER

PURPOSE: to convert alpha-numeric numbers to floating or fixed point numbers.

METHOD: After initially determining the sign of the number, the DO LOOP ending at statement 6 scans each character beginning at N1. The DO LOOP ending at statement 3 terminates the outer DO LOOP if the character being compared is not an alpha-numeric number. The DO LOOP ending at statement 5 converts the alpha-numeric number to an actual number. Below statement 7, the multiplier correction is applied to the floating point number before returning to the calling program.

CALLED BY: READ

CALLS TO: NONE

	SUBROUTINE NUMBER IN1,N2,X,IX)	1
	COMMON /A/ A180)	2
	DIMENSION R(10)	3
	DATA B/'0', '1', '2', '3', '4', '5', '6', '7', '8', '9' /	4
	DATA AMNUS, PLUS, POINT, I-'-', '+', '*', '/',	5
	DATA AK, AM, AU, 'K', 'M', 'U' /	6
	N = N1	7
	NSIGN = 0	8
	II = -1	9
	IX = 0	10
	ISET = 0	11
	IF (A(N).EQ.PLUS) N=N+1	12
	IF (A(N).NE.AMNUS) GO TO 1	13
	NSIGN = 1	14
	N = N+1	15
C	1 DO 6 I=N,80	16
	IF (A(I).NE.POINT) GO TO 2	17
	ISET = 1	18
	GO TO 6	19
C	2 IF (ISET.EQ.1) II = II+1	20
	DO 3 K=1,10	21
	IF (A(I).EQ.B(K)) GO TO 4	22
C	3 CONTINUE	23
	GO TO 7	24
C	4 DO 5 K=1,10	25
	KK = K-1	26
	IF (A(I).EQ.B(K)) NUMB=KK	27
C	5 CONTINUE	28
	IX = NUMB*10*IX	29
	N2 = I+1	30
C	6 CONTINUE	31
	7 IF (NSIGN.EQ.1) IX = -IX	32
	Y = IX	33
	IF (II.LT.0) II = 0	34
	X = Y/(10**II)	35
	IF (A(N2).EQ.POINT) N2=N2+1	36
	IF (A(N2).EQ.AK) X = X*1000.	37
	IF (A(N2).EQ.AM) X = X*0.001	38
	IF (A(N2).EQ.AU) X = X*0.000001	39
	IF ((A(N2).EQ.AK).OR.(A(N2).EQ.AM).OR.(A(N2).EQ.AU)) N2=N2+1	40
	N1 = N2	41
	RETURN	42
	END	43
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POLPRT

PURPOSE: to control the plotting of the polar plot.

METHOD: This subroutine is the main subroutine in the polar plot package and is responsible for calling the various subroutines of the package.

The scale factor, S , must be changed according to the printer characteristics. The scale factor in this subroutine is set for ten, 10, characters per inch for the abscissa and eight, 8, characters per inch for the ordinate axis. Therefore $S = 10./8$.

After initializing $DATA_X$, $DATA_Y$, and X , the input data, Y , is scanned to determine the normalizing factor. If this normalizing factor is less than $1.E-32$, an error statement is printed and the plotting is aborted.

In the DO LOOP ending with statement 8, each line of the polar plot is printed after a call is made to PTPLOT to establish the polar grid information. The variable, DIM, is used to as a scaling factor for the polar plot. The value of 1.0 will cause all of input data to be plotted, however, if only the values less than one-half of the normalizing factor are of interest, then DIM can be set to .5. This will enlarge of the center of the polar plot.

CALLED BY: MAIN

CALLS TO: PTPLOT

SART

```

SUBROUTINE POLPRT (NAME,Y)
COMMON /SYM,LINE
DIMENSION X(360), Y(360), DATA(360), DATAY(360), LINE(130), ISYM(
114)
DIMENSION TITLA(2), TITL2(2)
DATA TITLA/'PHI ', 'THET'/
N = 360
DIM = 1.0
NST = 1
KST = 1

S IS SCALE FACTOR OF PRINTER:
ABSCISSA CHAR. PER INCH / ORDINATE CHAR. PER INCH

S = 10.D/8.D

ZERO DATA AND DATAY

DO 1 IA=1,N
D = 1A-1
DATA X(IA) = D.D
DATA Y(IA) = D.D
1 X(IA) = D*3.1415927/180.D

FACTOR IS THE NORMALIZING DIVISOR
FACTOR = Y(1)

DO 2 IA=2,N
2 IF (FACTOR.LT.Y(IA)) FACTOR=Y(IA)

IF (NAME.EQ.1) TITL1=TITLA(1)
IF (NAME.EQ.2) TITL1=TITLA(2)
IF ((NAME.EQ.3).OR.(NAME.EQ.4).OR.(NAME.EQ.7).OR.(NAME.EQ.8)) TITL
12(1)=TITLA(1)
IF ((NAME.EQ.5).OR.(NAME.EQ.6).OR.(NAME.EQ.9).OR.(NAME.EQ.10)) TIT
12(1)=TITLA(2)
IF ((NAME.EQ.3).OR.(NAME.EQ.5).OR.(NAME.EQ.7).OR.(NAME.EQ.9)) TITL
12(2)=TITLA(1)
IF ((NAME.EQ.4).OR.(NAME.EQ.6).OR.(NAME.EQ.8).OR.(NAME.EQ.10)) TIT
12(2)=TITLA(2)
IF (FACTOR.GT.1.E-32) GO TO 3
IF (NAME.LE.2) WRITE (6,9) TITL1
IF (NAME.GE.3) WRITE (6,10) TITL2
RETURN

NORMALIZE DATA TO ONE

3 DO 4 IA=1,N
4 Y(IA) = Y(IA)/FACTOR

IF (NAME.LE.2) WRITE (6,11) TITL1,FACTOR
IF ((NAME.GE.3).AND.(NAME.LE.6)) WRITE (6,13) TITL2,FACTOR
IF (NAME.GE.7) WRITE (6,12) TITL2,FACTOR
FILL DATA AND DATAY ARRAY FROM X AND Y ARRAY

DO 5 IA=1,N
DATA X(IA) = Y(IA)*COS(X(IA))
5 DATA Y(IA) = Y(IA)*SIN(X(IA))

SORT DATA BY ORDINATE MAGNITUDE

CALL SART (DATA,X,DATAY,N)

DATA AND DATAY ARE SORTED BY DESENDING MAGNITUDE ON THE DATAY VAL
SET UP FOR PLOTTING POLAR GRID WITH DATA

DO 8 IYY=1,81
CALL PIPLLOT (IYY,5)

LINE IS RETURNED WITH POLAR GRID INFORMATION

SET UP 'Y' 8IN SIZE UPPER AND LOWER LIMITS
ULL IS THE LOWER 8IN LIMIT
UL IS THE UPPER 8IN LIMIT

8IN = DIM/80.D
ULL = DIM-(2*IYY-1)*8IN
UL = ULL+2*8IN

CYCLE THROUGH DATA TO FIND WHICH ONES FALL IN 'Y' 8INS

IF (NST.GT.N) GO TO 7

DO 6 JJ=NST,N

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	IF (OATAYIJJ).LT.ULL) GO TO 7	97
	KST = JJ	98
	AMAG = SQRT(OATAX(JJ)*OATAXIJJ)+OATAYIJJ)*OATAYIJJ))	99
C	CHECK THAT MAGNITUDE IS NOT OVER DIM	100
C		101
C	IF (AMAG.GT.DIM) GO TO 6	102
C		103
C	OK IS THE FINAL LINE POSITION FOR THE '**	104
C		105
	OK = OATAXIJJ)*S*40.0/DIM*61.0	106
	IF (OK.LT.10.0) GO TO 6	107
	K = INT(OK)	108
	K = ABS(K)	109
	OK = ABS(OK)	110
	IF ((OK-K).GT.0.5) K=K+1	111
	IF (OK.LT.10.0.OR.OK.GT.111.0) GO TO 6	112
	LINE(K) = ISYM(4)	113
6	CONTINUE	114
C		115
7	CONTINUE	116
	NST = KST+1	117
C		118
C	PRINT OUT ONE LINE OF PLOT	119
C		120
	WRITE (6,14) LINE	121
8	CONTINUE	122
C		123
	RETURN	124
C		125
	*9 FORMAT (10X,1A4,' COMPONENT OF THE ELECTRIC FIELO IS LESS'/10X,	126
	1 'THAN 1.E-64, THEREFORE THIS FIELO WAS NOT '/10X,'PLOTTEO. EXEC	127
	2UTION WILL CONTINUE AS NORMAL.'//)	128
10	FORMAT (10X,'THE MAXIMUM VALUE OF THE BISTATIC PATTERN FOR '/	129
	1 10X,1A4,'-',1A4,' (INCIDENT-SCATTEREO) IS LESS THAN '/	130
	2 10X,' 1.E-30.) POLAR PLOT NOT CALLED.'//)	131
11	FORMAT 1'1',1A4,' ELECTRIC FIELO ANTENNA PATTERN FOR SPECIFIED PLA	132
	INE,'9X,'NORMALIZING FACTOR='',E10.5)	133
12	FORMAT 1'1BISTATIC SCATTERING PATTERN FOR',1A4,'-',1A4,'(INCIDENT-	134
	1SCATTEREO) POLARIZATION,'9X,'NORMALIZING FACTOR='',E10.5)	135
13	FORMAT 1'1BACKSCATTERING PATTERN FOR',1A4,'-',1A4,'1INCIDENT-SCATT	136
	1EREO) POLARIZATION,'9X,'NORMALIZING FACTOR='',E10.5)	137
14	FORMAT 11X,130A1)	138
	END	139
		140

PTPLOT

PURPOSE: to establish the grid information for the
polar plot.

METHOD: In the DO LOOP ending at statement 1 the
alpha-numeric characters are transferred to ISYN in order
to pass via COMMON to other subroutines. In the statements
following statement 2, the equations for the plotted
concentric circles are established. Below statement 7 the
grid marks on the 090-270 axis are inserted.

CALLED BY: POLPRT

CALLS TO: LINECK
 NUMB

READ

PURPOSE: to interpret and translate the input data cards.

METHOD: The program utilizes free format for the data cards, that is, the program uses character recognition to determine which parameters are being read. In the IF statements containing A(1), A(2), A(3), and A(4), the first four characters on the data card are compared to the first four letters of the key words. This will determine the type of parameters that card contains. The other IF statements determine which parameters are being read.

Subroutine BLNK is called to remove the blank spaces on the parameter cards. Subroutines EQUAL and LEFT are called to determine the position of the equal character and the left paren, respectively. Subroutine NUMBER is called to convert the alpha-numeric characters to numbers, either fixed or floating point. This numerical value is assigned to the parameter just determined.

A detailed explanation of the data cards is found in appendix II titled "USERS MANUAL".

CALLED BY: BLNK
EQUAL
LEFT
NUMBER

```

SUBROUTINE READ (IA,IB,IBISC,ICARD,IGAIN,IGRO,INEAR,INT,ISCAT,IWR,
1 IFLAG,KFLAG,KGEN,LOAD,LZD,MSG,NBAP,NBIP,NFFP,NGEN,NM,NP,ABAP,ABAT,
2 AFTP,AFPT,ABIP,ABIT,AM,BM,CM,ER2,ER3,ER4,FMC,HGT,PHAF,PHAI,PHIF,
3 HIL,PHSF,PHSI,PHAF,THAI,THIF,THIL,THSF,THSI,SIG2,SIG3,SIG4,TD2,TD3
4 VOLT,X,XNP,Y,YNP,Z,ZLLD,ZNP,STEP)
COMMON /A/ AIRO)
COMPLEX VOLT(1),ZLLD(1)
DIMENSION (A(1),IB(1),XI(1),Y(1),Z(1),KGEN(1),KFLAG(1)
DIMENSION XNP(1),YNP(1),ZNP(1),LZD(1)
DATA AA,AB,AC,AD,AE,AF,AG,AH,AI,AK,AL,AMA,AN,AO,AP,AQ,AR,AS,AT,AU,
IAW,AX,'A','B','C','D','E','F','G','H','I','K','L','M','N','O','P',
2 'Q','R','S','T','U','V','W','X'
DATA BLANK,COMMA,MINUS,PLEFT,POINT,RIGHT,SLANT/' ','-','.',',',
1 '','/','/
RAD = 57.295779
INT = 4
IBISC = -1
IGAIN = -1
INEAR = -1
ISCAT = -1
IWR = -1
IF (IFLAG.EQ.6) GO TO 2
IF (MSG.NE.0) GO TO 4
1 READ (5,76,END=72) A
2 IF ((A(1).NE.AC).OR.(A(2).NE.BLANK).OR.(A(3).NE.BLANK).OR.(A(4).NE
1 .BLANK)) GO TO 3
WRITE (6,74) A
GO TO 1
3 WRITE (6,75)
GO TO 5
4 READ (5,76,END=72) A
5 ICARD = ICARD+1
WRITE (6,77) (ICARD,A
IF (MSG.NE.0).AND.(A(1).EQ.AE).AND.(A(2).EQ.AN).AND.(A(3).EQ.AO)
1) GO TO 6
IF ((MSG.NE.0).AND.(A(1).EQ.AS).AND.(A(2).EQ.AT).AND.(A(3).EQ.AO)
1.AND.(A(4).EQ.AP))) GO TO 69
IF ((A(1).EQ.AC).AND.(A(2).EQ.BLANK).AND.(A(3).EQ.BLANK).AND.(A(4)
1.EQ.BLANK)) GO TO 73
IF (MSG.GT.0) GO TO 4
CALL BLNK (A)
N = 4
C
C
C
INSULATION
IF ((A(1).NE.A).OR.(A(2).NE.AN).OR.(A(3).NE.AS).OR.(A(4).NE.AU))
1 GO TO 10
KFLAG(20) = 1
C
C
CALL LEFT (N)
6 IF ((A(N).NE.AR).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AO).OR.(A(N+3).NE
1 .A)) GO TO 7
KFLAG(4) = 1
CALL EQUAL (N)
CALL NUMBER (N,N2,X1,IX)
BM = X1
IF (A(N2).EQ.RIGHT) GO TO 4
IF (A(N2).NE.SLANT) GO TO 71
N = N2+1
GO TO 6
C
7 IF ((A(N).NE.AD).OR.(A(N+1).NE.AL).OR.(A(N+2).NE.AE).OR.(A(N+3).NE
1 .A)) GO TO 8
KFLAG(6) = 1
CALL EQUAL (N)
CALL NUMBER (N,N2,X1,IX)
ER2 = X1
IF (A(N2).EQ.RIGHT) GO TO 4
IF (A(N2).NE.SLANT) GO TO 71
N = N2+1
GO TO 6
C
8 IF ((A(N).NE.AC).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AN).OR.(A(N+3).NE
1 .A)) GO TO 9
KFLAG(5) = 1
CALL EQUAL (N)
CALL NUMBER (N,N2,X1,IX)
SIG2 = X1
IF (A(N2).EQ.RIGHT) GO TO 4
IF (A(N2).NE.SLANT) GO TO 71
N = N2+1
GO TO 6
C
9 IF ((A(N).NE.AL).OR.(A(N+1).NE.AD).OR.(A(N+2).NE.AS).OR.(A(N+3).NE
1 .A)) GO TO 71
KFLAG(7) = 1
CALL EQUAL (N)
CALL NUMBER (N,N2,X1,IX)
TD2 = X1
IF (A(N2).EQ.RIGHT) GO TO 4
IF (A(N2).NE.SLANT) GO TO 71
N = N2+1
GO TO 6
C
C
C
WIRE

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10 IF ((A(1).NE.AW).OR.(A(2).NE.AI).OR.(A(3).NE.AR).OR.(A(4).NE.AE))
  1GO TO 13
  CALL LEFT (N)
C
11 IF ((A(N).NE.AR).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AD).OR.(A(N+3).NE
  1.AI)) GO TO 12
  KFLAG(2) = 1
  CALL EQUAL (N)
  CALL NUMBER (N,N2,X1,IX)
  AM = X1
  IF (A(N2).EQ.RIGHT) GO TO 4
  IF (A(N2).NE.SLANT) GO TO 71
  N = N2+1
  GO TO 11
C
12 IF ((A(N).NE.AC).OR.(A(N+1).NE.AD).OR.(A(N+2).NE.AN).OR.(A(N+3).NE
  1.AO)) GO TO 71
  KFLAG(3) = 1
  CALL EQUAL (N)
  CALL NUMBER (N,N2,X1,IX)
  CM = X1
  IF (A(N2).EQ.RIGHT) GO TO 4
  IF (A(N2).NE.SLANT) GO TO 71
  N = N2+1
  GO TO 11
C
  EXTERNAL MEDIUM
C
13 IF ((A(1).NE.AE).OR.(A(2).NE.AX).OR.(A(3).NE.AT).OR.(A(4).NE.AE))
  1GO TO 17
  KFLAG(8) = 1
  CALL LEFT (N)
C
14 IF ((A(N).NE.AC).OR.(A(N+1).NE.AD).OR.(A(N+2).NE.AN).OR.(A(N+3).NE
  1.AO)) GO TO 15
  KFLAG(9) = 1
  CALL EQUAL (N)
  CALL NUMBER (N,N2,X1,IX)
  SIG3 = X1
  IF (A(N2).EQ.RIGHT) GO TO 4
  IF (A(N2).NE.SLANT) GO TO 71
  N = N2+1
  GO TO 14
C
15 IF ((A(N).NE.AD).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AE).OR.(A(N+3).NE
  1.AL)) GO TO 16
  KFLAG(10) = 1
  CALL EQUAL (N)
C
  CALL NUMBER (N,N2,X1,IX)
  ER3 = X1
  IF (A(N2).EQ.RIGHT) GO TO 4
  IF (A(N2).NE.SLANT) GO TO 71
  N = N2+1
  GO TO 14
C
16 IF ((A(N).NE.AL).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AS).OR.(A(N+3).NE
  1.AS)) GO TO 71
  KFLAG(11) = 1
  CALL EQUAL (N)
  CALL NUMBER (N,N2,X1,IX)
  TO3 = X1
  IF (A(N2).EQ.RIGHT) GO TO 4
  IF (A(N2).NE.SLANT) GO TO 71
  N = N2+1
  GO TO 14
C
  LOAD
C
17 IF ((A(1).NE.AL).OR.(A(2).NE.AO).OR.(A(3).NE.AA).OR.(A(4).NE.AD))
  1GO TO 18
  KFLAG(14) = 1
  GO TO 19
18 IF ((A(1).NE.A).OR.(A(2).NE.AMA).OR.(A(3).NE.AP).OR.(A(4).NE.AE))
  1GO TO 22
  KFLAG(24) = 1
19 I = 1
  CALL LEFT (N)
20 CALL NUMBER (N,N2,X1,IX)
  IF (IX.LE.0) GO TO 21
  LZD(1) = IX
  N = N2+1
  CALL NUMBER (N,N2,X1,IX)
  RMAG = X1
  N = N2+1
  CALL NUMBER (N,N2,X1,IX)
  RUEG = X1
  RREAL = RMAG*COS(RUEG/RAO)
  RIMAG = RMAG*SIN(RUEG/RAO)
  ZLLO(1) = CMPLX(RREAL,RIMAG)
  LOAD = I
  IF (A(N2).EQ.RIGHT) GO TO 4
  IF (A(N2).NE.SLANT) GO TO 71
  I = I+1
  N = N2+1
  GO TO 20

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21	KFLAG(24) = -1	193
	LOAD = -1	194
	GO TO 4	195
C		196
C	FREQUENCY	197
C		198
22	IF ((A(1).NE.AF).OR.(A(2).NE.AR).OR.(A(3).NE.AE).OR.(A(4).NE.AQ))	199
	GO TO 23	200
	KFLAG(1) = 1	201
	CALL LEFT (N)	202
	CALL NUMBER (N,N2,X1,(X)	203
	FMC = X1	204
	GO TO 4	205
C		206
C	PLOT	207
C		208
23	IF ((A(1).NE.AP).OR.(A(2).NE.AL).OR.(A(3).NE.AO).OR.(A(4).NE.AT))	209
	GO TO 31	210
	KFLAG(22) = 1	211
	CALL LEFT (N)	212
C		213
24	IF ((A(N).NE.AF).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AR).OR.(A(N+3).NE	214
	1.AF)) GO TO 25	215
	GAIN = 1	216
	NFFP = 1	217
	GO TO 27	218
25	IF ((A(N).NE.AB).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AS).OR.(A(N+3).NE	219
	1.AT)) GO TO 26	220
	BISC = 1	221
	NBIP = 1	222
	GO TO 27	223
26	IF ((A(N).NE.AB).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AC).OR.(A(N+3).NE	224
	1.AK)) GO TO 71	225
	SCAT = 1	226
	NBAP = 1	227
C		228
C		229
C		230
27	DO 28 (=N,BO	231
	K = 1	232
	(F(A(1)).EQ.SLANT) GO TO 29	233
28	CONTINUE	234
C		235
C		236
C		237
	GO TO 71	238
29	N = K	239
	IF ((A(N).NE.AT).OR.(A(N+1).NE.AH).OR.(A(N+2).NE.AE).OR.(A(N+3).NE	240
	1.AT)) GO TO 30	241
	CALL EQUAL (N)	242
	CALL NUMBER (N,N2,X1,IX)	243
	IF (NFFP.EQ.1) AFFP=X1	244
	IF (NBIP.EQ.1) ABIP=X1	245
	IF (NBAP.EQ.1) ABAT=X1	246
	IF (A(N2).EQ.RIGHT) GO TO 4	247
	IF (A(N2).NE.SLANT) GO TO 71	248
	N = N2+1	249
	GO TO 24	250
30	IF ((A(N).NE.AP).OR.(A(N+1).NE.AH).OR.(A(N+2).NE.AI)) GO TO 71	251
	CALL EQUAL (N)	252
	CALL NUMBER (N,N2,X1,(X)	253
	IF (NFFP.EQ.1) AFFP=X1	254
	IF (NBIP.EQ.1) ABIP=X1	255
	IF (NBAP.EQ.1) ABAT=X1	256
	IF (A(N2).EQ.RIGHT) GO TO 4	257
	IF (A(N2).NE.SLANT) GO TO 71	258
	N = N2+1	259
	GO TO 24	260
C		261
C	OUTPUT	262
C		263
31	IF ((A(1).NE.AO).OR.(A(2).NE.AU).OR.(A(3).NE.AT).OR.(A(4).NE.AP))	264
	GO TO 44	265
	KFLAG(22) = 1	266
	CALL LEFT (N)	267
C		268
32	IF ((A(N).NE.AB).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AS).OR.(A(N+3).NE	269
	1.AT)) GO TO 33	270
	KFLAG(118) = 1	271
	BISC = 1	272
	CALL EQUAL (N)	273
	CALL NUMBER (N,N2,X1,(X)	274
	PHSI = X1	275
	N = N2+1	276
	CALL NUMBER (N,N2,X1,(X)	277
	PHSF = X1	278
	N = N2+1	279
	CALL NUMBER (N,N2,X1,(X)	280
	THSI = X1	281
	N = N2+1	282
	CALL NUMBER (N,N2,X1,(X)	283
	THSF = X1	284
	IF (A(N2).EQ.RIGHT) GO TO 4	285
	IF (A(N2).NE.SLANT) GO TO 71	286
	N = N2+1	287
	GO TO 32	288

C	33 IF ((A(N).NE.AF).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AR).OR.(A(N+3).NE	289
	I.AF)) GO TO 34	290
	KFLAG(16) = 1	291
	IGAIN = 1	292
	CALL EQUAL (N)	293
	CALL NUMBER (N,N2,X1,IX)	294
	PHAI = X1	295
	N = N2+1	296
	CALL NUMBER (N,N2,X1,IX)	297
	PHAF = X1	298
	N = N2+1	299
	CALL NUMBER (N,N2,X1,IX)	300
	THAI = X1	301
	N = N2+1	302
	CALL NUMBER (N,N2,X1,IX)	303
	THAF = X1	304
	IF (A(N2).EQ.RIGHT) GO TO 4	305
	IF (A(N2).NE.SLANT) GO TO 71	306
	N = N2+1	307
	GO TO 32	308
C	34 IF ((A(N).NE.AN).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AA).OR.(A(N+3).NE	309
	I.AR)) GO TO 40	310
	KFLAG(19) = 1	311
	INEAR = 2	312
	CALL EQUAL (N)	313
	IF (A(N).EQ.PLEFT) GO TO 35	314
	INEAR = 1	315
	I = 1	316
	GO TO 36	317
C		318
C		319
C		320
	35 DO 37 L=1,50	321
	I = L	322
	N = N+1	323
	36 CALL NUMBER (N,N2,X1,IX)	324
	XNP(1) = X1	325
	N = N2+1	326
	CALL NUMBER (N,N2,X1,IX)	327
	YNP(1) = X1	328
	N = N2+1	329
	CALL NUMBER (N,N2,X1,IX)	330
	ZNP(1) = X1	331
	IF (INEAR.EQ.1) GO TO 39	332
	INEAR = L+1	333
	IF (A(N2).EQ.RIGHT) GO TO 38	334
		335
		336
	N = N2	337
	37 CONTINUE	338
C		339
C		340
C		341
	GO TO 71	342
	38 N2 = N2+1	343
	INEAR = INEAR-1	344
	IF (A(N2).EQ.RIGHT) GO TO 4	345
	IF (A(N2).NE.SLANT) GO TO 71	346
	N = N2+1	347
	GO TO 32	348
C		349
	40 IF ((A(N).NE.AB).OR.(A(N+1).NE.AA).OR.(A(N+2).NE.AC).OR.(A(N+3).NE	350
	I.AK)) GO TO 41	351
	KFLAG(17) = 1	352
	ISCAT = 1	353
	CALL EQUAL (N)	354
	CALL NUMBER (N,N2,X1,IX)	355
	PH11 = X1	356
	N = N2+1	357
	CALL NUMBER (N,N2,X1,IX)	358
	PH1F = X1	359
	N = N2+1	360
	CALL NUMBER (N,N2,X1,IX)	361
	TH11 = X1	362
	N = N2+1	363
	CALL NUMBER (N,N2,X1,IX)	364
	TH1F = X1	365
	IF (A(N2).EQ.RIGHT) GO TO 4	366
	IF (A(N2).NE.SLANT) GO TO 71	367
	N = N2+1	368
	GO TO 32	369
C		370
	41 IF ((A(N).NE.AC).OR.(A(N+1).NE.AU).OR.(A(N+2).NE.AR).OR.(A(N+3).NE	371
	I.AR)) GO TO 43	372
	KFLAG(15) = 1	373
	IWR = 1	374
C		375
C		376
C		377
	DO 42 K=N,80	378
	IF (A(K).EQ.RIGHT) GO TO 4	379
	N = K+1	380
	IF (A(K).EQ.SLANT) GO TO 32	381
	42 CONTINUE	382
C		383
	GO TO 71	384

C	43	IF ((A(N).NE.AS(.OR.)A(N+1).NE.AT).OR.)A(N+2).NE.AE).OR.)A(N+3).NE	385
		1.AP)I GO TO 71	386
		CALL EQUAL (N)	387
		CALL NUMBER (N,N2,X1,X)	388
		STEP = X1	389
		IF (A(N2).EQ.RIGHT) GO TO 4	390
		IF (A(N2).NE.SLANT) GO TO 71	391
		N = N2+1	392
		GO TO 32	393
C		FEED POINT	394
C			395
	44	IF ((A(1).NE.AF).OR.(A(2).NE.AE).OR.)A(3).NE.AE).OR.)A(4).NE.AO))	396
		GO TO 45	397
		KFLAG(13) = 1	398
		GO TO 46	399
	45	IF ((A(1).NE.AG).OR.(A(2).NE.AE).OR.)A(3).NE.AN).OR.(A(4).NE.AE))	400
		GO TO 49	401
		KFLAG(23) = 1	402
	46	NGEN = 0	403
		CALL LEFT (N)	404
	47	CALL NUMBER (N,N2,X1,X)	405
		NGEN = NGEN+1	406
		KGEN(NGEN) = 1X	407
		IF (A(N2).EQ.RIGHT) GO TO 4	408
		N = N2+1	409
		CALL NUMBER (N,N2,X1,X)	410
		VMAG = X1	411
		N = N2+1	412
		CALL NUMBER (N,N2,X1,X)	413
		VOEG = X1	414
		VREAL = VMAG*COS(VOEG/RAO)	415
		VIMAG = VMAG*SIN(VOEG/RAO)	416
		VOLT(NGEN) = CMPLX(VREAL,VIMAG)	417
		IF (A(N2).EQ.RIGHT) GO TO 4	418
		IF (A(N2).NE.SLANT) GO TO 71	419
		IF ((A(N2).EQ.SLANT).AND.(A(N2+1).EQ.BLANK)) GO TO 48	420
		N = N2+1	421
		GO TO 47	422
	48	READ (5,76) A	423
		ICARO = ICARO+1	424
		WRITE (6,77) ICARO,A	425
		N = 1	426
		CALL BLNK (A)	427
		GO TO 47	428
C			429
C			430
			431
			432

C		DESCRIPTION	433
C			434
	49	IF ((A(1).NE.AO(.OR.)A(2).NE.AE(.OR.)A(3).NE.AS(.OR.)A(4).NE.AC))	435
		GO TO 52	436
		KFLAG(12) = 1	437
		J = 0	438
		CALL LEFT (N)	439
	50	CALL NUMBER (N,N2,X1,X)	440
		J = J+1	441
		NH = J	442
		IA(J) = 1X	443
		N = N2+1	444
		CALL NUMBER (N,N2,X1,X)	445
		IB(J) = 1X	446
		IF (A(N2).EQ.RIGHT) GO TO 4	447
		IF (A(N2).NE.SLANT) GO TO 71	448
		IF ((A(N2).EQ.SLANT).AND.(A(N+1).EQ.BLANK)) GO TO 51	449
		N = N2+1	450
		GO TO 50	451
	51	READ (5,76) A	452
		ICARO = ICARO+1	453
		CALL BLNK (A)	454
		WRITE (6,77) ICARO,A	455
		N = 1	456
		GO TO 50	457
C		GEOMETRY	458
C			459
	52	IF ((A(1).NE.AG).OP.)A(2).NE.AE).OR.(A(3).NE.AO).OR.(A(4).NE.AN))	460
		GO TO 55	461
		KFLAG(12) = 1	462
		JJ = 0	463
		CALL LEFT (N)	464
	53	CALL NUMBER (N,N2,X1,X)	465
		JJ = JJ+1	466
		NP = JJ	467
		X(JJ) = X1	468
		N = N2+1	469
		CALL NUMBER (N,N2,X1,X)	470
		Y(JJ) = X1	471
		N = N2+1	472
		CALL NUMBER (N,N2,X1,X)	473
		Z(JJ) = X1	474
		IF (A(N2).EQ.RIGHT) GO TO 4	475
		IF (A(N2).NE.SLANT) GO TO 71	476
		IF ((A(N2).EQ.SLANT).AND.(A(N+1).EQ.BLANK)) GO TO 54	477
		N = N2+1	478
		GO TO 53	479
			480

54	READ (5,76) A	481
	ICARO = ICARD+1	482
	WRITE (6,77) (ICARO,A	483
	CALL BLNK (A)	484
	N = 1	485
	GO TO 53	486
C	INTERVAL FOR CALCULATION	487
C		488
55	IF ((A(1).NE.A(1)).OR.(A(2).NE.AN).OR.(A(3).NE.AT).OR.(A(4).NE.AE))	489
	IGOTO 56	490
	KFLAG(21) = 1	491
	CALL LEFT (N)	492
	CALL NUMBER (N,N2,X1,IX)	493
	INT = IX	494
	IF (A(N2).EQ.RIGHT) GO TO 4	495
	GO TO 71	496
C		497
C	GROUND	498
C		499
56	IF ((A(1).NE.AG).OR.(A(2).NE.AR).OR.(A(3).NE.AO).OR.(A(4).NE.AU))	500
	IGOTO 66	501
	KFLAG(25) = 1	502
	KFLAG(26) = 1	503
	IGRO = 2	504
	CALL LEFT (N)	505
57	IF ((A(N).NE.AP).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AR).OR.(A(N+3).NE	506
	AF)) GO TO 58	507
	IGRO = 1	508
	GO TO 64	509
58	IF ((A(N).NE.AG).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AD).OR.(A(N+3).NE	510
	AO)) GO TO 59	511
	ER4 = 30.	512
	SIG4 = .02	513
	GO TO 64	514
59	IF ((A(N).NE.AP).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AO).OR.(A(N+3).NE	515
	AR)) GO TO 60	516
	ER4 = 4.	517
	SIG4 = .001	518
	GO TO 64	519
60	IF ((A(N).NE.AS).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AA)) GO TO 61	520
	ER4 = 80.	521
	SIG4 = 4.	522
	GO TO 64	523
61	IF ((A(N).NE.AH).OR.(A(N+1).NE.AE).OR.(A(N+2).NE.AI).OR.(A(N+3).NE	524
	AG)) GO TO 62	525
	CALL EQUAL (N)	526
	CALL NUMBER (N,N2,X1,IX)	527
		528
	HGT = X1	529
	IF (A(N2).EQ.RIGHT) GO TO 4	530
	IF (A(N2).NE.SLANT) GO TO 71	531
	N = N2+1	532
	GO TO 57	533
62	IF ((A(N).NE.AC).OR.(A(N+1).NE.AO).OR.(A(N+2).NE.AN).OR.(A(N+3).NE	534
	AO)) GO TO 63	535
	CALL EQUAL (N)	536
	CALL NUMBER (N,N2,X1,IX)	537
	SIG4 = X1	538
	IF (A(N2).EQ.RIGHT) GO TO 4	539
	IF (A(N2).NE.SLANT) GO TO 71	540
	N = N2+1	541
	GO TO 57	542
63	IF ((A(N).NE.AD).OR.(A(N+1).NE.AI).OR.(A(N+2).NE.AE).OR.(A(N+3).NE	543
	AI)) GO TO 71	544
	CALL EQUAL (N)	545
	CALL NUMBER (N,N2,X1,IX)	546
	ER4 = X1	547
	IF (A(N2).EQ.RIGHT) GO TO 4	548
	IF (A(N2).NE.SLANT) GO TO 71	549
	N = N2+1	550
	GO TO 57	551
C		552
C		553
C		554
64	OD 65 K=N,80	555
	IF (A(K).EQ.RIGHT) GO TO 4	556
	N = K+1	557
	IF (A(K).EQ.SLANT) GO TO 57	558
65	CONTINUE	559
C		560
C		561
C		562
C	GO TO 71	563
C		564
66	IF ((A(1).NE.AS).OR.(A(2).NE.AT).OR.(A(3).NE.AO).OR.(A(4).NE.AP))	565
	IGOTO 67	566
	IFLAG = 2	567
	RETURN	568
C		569
67	IF ((A(1).NE.AC).OR.(A(2).NE.AH).OR.(A(3).NE.AA).OR.(A(4).NE.AN))	570
	IGOTO 68	571
	IFLAG = 3	572
	RETURN	573
C		574
68	IF ((A(1).NE.AE).OR.(A(2).NE.AN).OR.(A(3).NE.AO)) GO TO 71	575
		576
	IFLAG = 1	577
	RETURN	578
69	IFLAG = 5	579
	RETURN	580
70	IFLAG = 4	581
	RETURN	582
71	MSG = 1	583
	KFLAG(30) = ICARO	584
	GO TO 4	585
72	IF (IFLAG.NE.5) WRITE (6,78)	586
	IFLAG = 5	587
	RETURN	588
C		589
73	IFLAG = 6	590
	ICARO = ICARD-1	591
	RETURN	592
C		593
C		594
C		595
74	FORMAT (5X,80A1)	596
75	FORMAT (////5X,'DATA CAROS'//)	597
76	FORMAT (80A1)	598
77	FORMAT (6X,12,2X,80A1)	599
78	FORMAT (' ***** END CARO/STOP CARD MISSING*****')	600
	END	601

RITE

PURPOSE: to generate a list of branch currents from
the input loop currents.

METHOD: The generation of branch currents is
accomplished in the DO LOOP ending at statement 2. The
branch currents are stored in CJ(I) by the latter part of
the DO LOOP ending at statement 3. If the branch currents
are requested for output (IWR positive), the DO LOOP ending
at statement 5 accomplishes this.

CALLED BY: GANT1

 · GFFLD

CALLS TO: NONE

```

SUBROUTINE RITE(IA,IB,INM,IWR,I1,I2,I3,M0,N0,NM,CJ,CG,IGRO1
COMPLEX CJ(I),CG(I),CJA,CJB
DIMENSION IA(I), IB(I), I1(I), I2(I), I3(I), M0(INM,4), N0(I)
AMAX = .0

DO 3 K=1,NM
KA = IA(K)
KB = IB(K)
CJA = (.0,.0)
CJB = (.0,.0)
NOK = ND(K)

DO 2 I=1,NOK
I = MO(K,I)
FI = I.
IF (KB.EQ.I2(I)) GO TO 1
IF (KB.EQ.I1(I)) FI=-1.
CJA = CJA+FI*CJ(I)
GO TO 2
1 IF (KA.EQ.I3(I)) FI=-1.
CJB = CJB+FI*CJ(I)
2 CONTINUE

CG(K) = CJA
KK = K+NM
CG(KK) = CJB
ACJ = CABS(CJA)
BCJ = CABS(CJB)
IF (ACJ.GT.AMAX) AMAX=ACJ
IF (BCJ.GT.AMAX) AMAX=BCJ
3 CONTINUE

IF (IWR.GT.0) GO TO 4
RETURN
4 IF (AMAX.LE.0.) AMAX=1.
WRITE (6,8)
NMG = NM
IF (IGRO.GT.0) NMG = NM/2

DO 5 K=1,NMG
CJA = CG(K)
KK = K+NM
CJB = CG(KK)
CCJA = CABS(CJA)

CCJB = CABS(CJB)
ACJ = CCJA/AMAX
BCJ = CCJB/AMAX
PA = .0
PB = .0
IF (ACJ.GT.0.) PA = 57.29578*ATAN2(AIMAG(CJA),REAL(CJA))
IF (BCJ.GT.0.) PB = 57.29578*ATAN2(AIMAG(CJB),REAL(CJB))
5 WRITE (6,7) K,IA(K),CJA,CCJA,ACJ,PA,IB(K),CJB,CCJB,BCJ,PB

WRITE (6,6)
RETURN

6 FORMAT (IHO)
7 FORMAT (2X,I2,2(2X,I2,X,E11.5,1X,E11.5,1X,E11.5,1X,F6.1)
11
8 FORMAT (/Z(46X,'NORMALIZED',5X)/' SEG',2(' NOOE',4X,'REAL',6X,'IMA
GINARY',3X,'MAGNITUDE',3X,'MAGNITUDE',3X,'PHASE'),1
ENO

```


SART

PURPOSE: to sort data for polar plot.

METHOD: This subroutine sorts the values of the points to be plotted by the polar plot package starting with the greatest positive value of y to the greatest negative value. In the DO LOOP ending at statement 1, the value of (x_i, y_i) is interchanged with the value of (x_j, y_j) if y_j is greater than y_i .

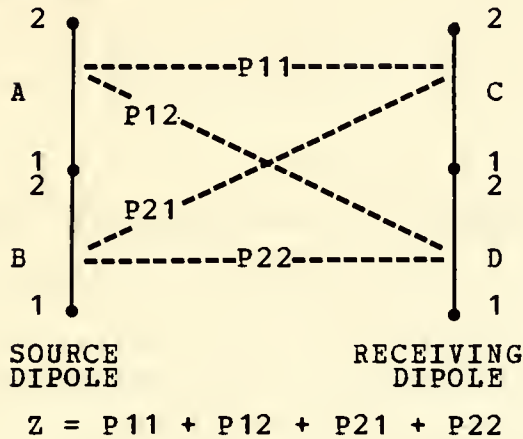
CALLED BY: POLPRT

CALLS TO: NONE

	SUBROUTINE SART (DATAx, DATAy, N)	
	DIMENSION DATAx(500), DATAy(500)	1
C	THIS ROUTINE SORTS DATA IN DATAy BY MAGNITUDE	2
C	NN = N-1	3
C	DO 2 I=1, NN	4
	NM = I+1	5
C	DO 1 J=NM, N	6
	IF (DATAy(I) .GE. DATAy(J)) GO TO 1	7
	STOR = DATAy(I)	8
	DATAy(I) = DATAy(J)	9
	DATAy(J) = STOR	10
	STOR = DATAx(I)	11
	DATAx(I) = DATAx(J)	12
	DATAx(J) = STOR	13
	1 CONTINUE	14
C	2 CONTINUE	15
C	RETURN	16
	END	17
		18
		19
		20
		21
		22
		23
		24

SGANT

PURPOSE: to calculate the mutual impedance between filamentary monopoles.



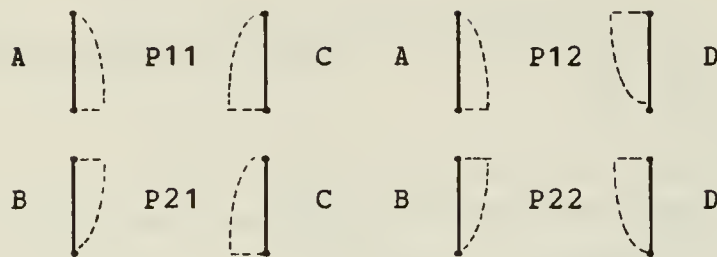
METHOD: In the induced emf formulation, the mutual impedance of coupled dipoles is

$$Z = - \int I_2(t) E_1(t) dt$$

where $I_2(t)$ denotes the current distribution (normalized to unit terminal current) on dipole 2, and $E_1(t)$ is the field of dipole 1 when it transmits with unit terminal current. Distance along the axis of dipole 2 is denoted by the coordinate t . E_1 may be expressed as the sum of the fields from each of the monopoles comprising dipole 1. Furthermore, the integral is the sum of the integrations over each of the monopoles comprising dipole 2. Thus, the dipole-dipole mutual impedance may be expressed as the sum of four monopole-monopole impedances.

It may be convenient to draw the above figure in terms of monopoles with the current distribution shown as dotted

lines. (The monopole letters remain the same.)



The surface impedance is calculated just above statement 2. $B01$ denotes J_0 / J_1 where J_0 and J_1 are the Bessel functions of order zero and one with complex argument, $ZARG$. It is assumed that all the wire segments have the same radius, conductivity and surface impedance.

In the DO LOOP ending with statement 3, $SGANT$ calculates the segment lengths $D(J)$. $DMIN$ and $DMAX$ denote the lengths of the shortest and longest segments. If the wire radius or the segment lengths are clearly beyond the range of thin-wire theory, N is set to zero at statement 4 followed by $RETURN$ to the main program to abort the calculation.

At statement 5, the program selects a segment K , and a few statements below this it selects another segment L . K is a segment of test dipole I , and L is a segment of expansion mode J . The mutual impedance between segments K and L is obtained by calling subroutine GGs or $GGMM$. In statement 18, this impedance is lumped into $C(MMM)$. The mutual impedance Z_{ij} between dipoles I and J is the sum of four segment-segment impedances.

The variables $IFLAG$ and $JFLAG$ are used if a ground plane is present for the calculation of the mutual impedance elements. If $IFLAG$ is equal to $JFLAG$, the mutual impedance

terms will not have the effects of a ground plane since both monopoles lie on the same side of the ground interface. If the monopoles are on the opposite sides of the interface (IFLAG not equal to JFLAG), the reflection coefficient correction must be applied to the mutual impedance elements. This same technique is applied in subroutines GNFLD and GFFLD.

In SGANT, segment K has endpoints KA and KB, and segment L has endpoints LA and LB. It is convenient to think of KA and KB as points 1 and 2 on segment K, and LA and LB as points 1 and 2 on L. The four segment-segment impedances can be defined as $P(IS,JS)$. The first subscript IS refers to the terminal point on segment K, and the second subscript JS refers to the terminal point on L. Thus IS=1 or 2 if dipole I has its terminal point I2(I) at KA (point 1) or KB (point 2), respectively. Similarly, JS=1 or 2 if mode J has its terminal point I2(J) at LA or LB. The impedances $P(IS,JS)$ are defined with the following reference directions for current flow: from point 1 toward point 2 on each segment. If dipole I has this same reference direction on segment K, FI=1; otherwise FI=-1. Similarly FJ=1 or -1 in accordance with the reference direction for mode J on segment L. In statement 18, $P(IS,JS)$ is multiplied by FI and FJ before its contribution is added to Z_{ij} .

Subroutine GGMM calculates the impedances $Q(KK,LL)$ which are like the $P(IS,JS)$ but have different conventions for reference directions and subscript meaning. The transformation from the Q impedances to the P impedances is accomplished in the DO LOOP ending with statement 13.

If the wire has finite conductivity, the appropriate modification is applied to the impedance matrix just above statement 15. The terms arising from the dielectric shell

on an insulated segment are obtained from subroutine DSHELL just above statement 16. Finally, the lumped loads, ZLD, are added to the diagonal elements of the impedance matrix in the DO LOOP ending at statement 23.

K is a segment of test dipole I, and L is a segment of expansion mode J. When the segment numbers K and L are equal, SGANT calls GGMM to obtain the mutual impedance between two filamentary electric monopoles. These monopoles are parallel and have the same length. Monopole K is positioned on the axis of the wire segment, and monopole L is on the surface of the same wire segment. Thus, the displacement is equal to the wire radius. The two monopoles are side-by-side with no stagger.

When segments K and L intersect, SGANT again calls GGMM for the mutual impedance between the two filamentary monopoles. Monopole K is situated on the axis of wire segment K, and monopole L is on the surface of wire segment L. The axes of segments K and L define a plane P, and monopole K lies in this plane. Monopole L is parallel with plane P and is displaced from it by a distance equal to the wire radius.

CALLED BY: MAIN

CALLS TO: CBES

 DSHELL

 GGMM

 GGS

```

SUBROUTINE SGANT (IA,IB,INM,INT,ISC,I1,I2,I3,JA,J8,MD,N,ND,NM,NP,A
1  IM,BM,C,CGD,CMH,D,EP2,EP3,ETA,FHZ,GAM,SGO,X,Y,Z,ZLO,ZS,ERR,IGRD)
2  CCMPLX ERR
3  CCMPLX ZG,ZH,ZS,EGD,GD,CGDS,SGDS,SGOT,8D1
4  CCMPLX P1,P2,P21,P22,Q1,Q12,Q21,Q22,EP2,EP,ETA,GAM,EP3
5  CCMPLX EPSILA,CWEA,BETA,ZARG
6  CCMPLX P(2,2),Q(2,2),CGD(1),SGD(1),C(1),ZLD(1)
7  DIMENSION X(1),Y(1),Z(1),Q(1),IA(1),IB(1),MD(1NM,4)
8  DIMENSION I1(1),I2(1),I3(1),JA(1),J8(1),ND(1),ISC(1)
9  DATA EO,TP,UO/8.854E-12,6.28318,1.2566E-6/
10 EP = EP3
11 ICC = (N*N*N)/2
12
13 DO 1 I=1,ICC
14   1 C(I) = (.D,.O)
15
16   C
17   ZS = (.D,.D)
18   IF (CMH.LE.O.) GO TO 2
19   OMEGA = TP*FHZ
20   EPSILA = CMPLX(ED,-CMH*1.E6/OMEGA)
21   CWEA = (.O,.I)*OMEGA*EPSILA
22   BETA = OMEGA*SGOT(UD)*CSORT(EPSILA-EP)
23   ZARG = BETA*AM
24   CALL CBFS (ZARG,8D1)
25   ZS = BETA*8D1/CWEA
26   2 ZH = ZS/(TP*AM*GAM)
27   DMIN = 1.E3D
28   DMAX = .D
29
30   C
31   DO 3 J=1,NM
32     K = IA(J)
33     L = IB(J)
34     DIJ = SORT((X(K)-X(L))**2+(Y(K)-Y(L))**2+(Z(K)-Z(L))**2)
35     IF (DIJ.LT.DMIN) DMIN=DIJ
36     IF (DIJ.GT.DMAX) DMAX=DIJ
37     EGD = CEXP(GAM*DIJ)
38     CGD(J) = (EGD+1./EGD)/2.
39     3 SGD(J) = (EGD-1./EGD)/2.
40
41   C
42   IF (DMIN.LT.2.*AM) GO TO 4
43   IF (CABS(GAM*AM).GT.O.D6) GO TO 4
44   IF (CABS(GAM*OMAX).GT.3.) GO TO 4
45   IF (AM.GT.O.) GO TO 5
46   4 CONTINUE
47   N=O
48   WRITE (6,24) AM,OMAX,DMIN
49
50   C
51   WRITE (6,25)
52
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C      IF (INO.EQ.0) GO TO 10
      SEGMENTS K AND L SHARE NO POINTS
      CALL GGS (X(KA),Y(KA),Z(KA),X(KB),Y(KB),Z(KB),X(LA),Y(LA),Z(LA),X(
100      LB),Y(LB),Z(LB),AM,DK,CGDS,SGDS,OL,SGOT,INT,ETA,GAM,P(1,1),P(1,2),
      ZP(2,1),P(2,2),ERR,IGRD)
      IGRD = NGRD
      GO TO 18
C      SEGMENTS K AND L SHARE ONE POINT (THEY INTERSECT)
10  KG = 0
      JM = KB
      JC = KA
      KF = 1
      (NO = (KB-LA)*(KB-LB)
      IF (INO.NE.0) GO TO 11
      JC = KB
      KF = -1
      JM = KA
      KG = 3
11  LG = 3
      JP = LA
      LF = -1
      IF (LB.EQ.JC) GO TO 12
      JP = LB
      LF = 1
      LG = 0
12  SGN = KF*LF
      CPS( = ((X(JP)-X(JC))*(X(JM)-X(JC))*1Y(JP)-Y(JC))*1Y(JM)-Y(JC))*(Z
123      (JP)-Z(JC))*1Z(JM)-Z(JC))/((OK*OL)
      CALL GMM (.0,DK,.0,OL,AM,CGDS,SGDS,SGOT,CPS1,ETA,GAM,Q(1,1),Q(1,2
124      ),Q(2,1),Q(2,2))
      IF (IGRD.GT.0) SGN=-SGN
C      DO 13 KK=1,2
      KP = (ABS(KK-KG)
C      DO 13 LL=1,2
      LP = (ABS(LL-LG)
      P(KP,LP) = SGN*Q(KK,LL)
13  CONTINUE
C      (GRD=NGRD
      GO TO 18
C      K=L (SELF REACTION OF SEGMENT K)
14  Q11 = (.0,.0)
      Q12 = (.0,.0)
      IF (CMM.LE.0.) GO TO 15
      GD = GAM*OK
      ZG = ZH/(SGDS**2)
      Q11 = ZG*(SGDS*CGDS-GD)/2.
      Q12 = ZG*(GD*CGDS-SGDS)/2.
15  ISCK = 1SCIK(
      P11 = (.0,.0)
      P12 = (.0,.0)
      IF (ISCK.EQ.0) GO TO 16
      IF (BM.LE.AM) GO TO 16
      CALL DSHELL (AM,BM,DK,CGDS,SGDS,EP2,EP,ETA,GAM,P11,P12)
16  Q11 = P11+Q11
      Q12 = P12+Q12
      CALL GMM (.0,DK,.0,OK,AM,CGDS,SGDS,SGOS,1.,ETA,GAM,P11,P12,P21,P2
161      ),Q11,Q12)
      Q11 = P11+Q11
      Q12 = P12+Q12
      P(1,1) = Q11
      P(1,2) = Q12
      P(2,1) = Q11
      P(2,2) = Q12
      IF (KA.NE.LA) GO TO 17
      GO TO 18
17  P(1,1) = -Q12
      P(1,2) = -Q11
      P(2,1) = -Q11
      P(2,2) = -Q12
18  C(MMM) = C(MMM)+F)*FJ*P(1,JS)
19  CONTINUE
C
C      DO 23 I=1,N
      MM = ((-1)*N-(1)-1)/2
      IJ = MM+1
      JJA = JA(I)
      J1 = JJA
      (I2 = I2(I)
      (I1 = I1(I)
      IF (I12.EQ.18(J1)) J1=J1+NM
      JJB = JB(I1)
      J2 = JJB
      IF (I12.EQ.18(J2)) J2=J2+NM
      C(IJ) = C(IJ)+ZC(IJ1)+ZC(IJ2)
      JJJ = JJA
C      DO 22 K=1,2
      NDJ = ND(JJJ)
C      DO 21 JJ=1,NQJ
      J = MO(JJJ,JJ)
      IF (J.EQ.1) GO TO 2)

```


	IF (I2(J).NE.II2) GO TO 21	193
	IJ = MM+J	194
	F1 = 1.	195
	IF (K.EQ.2) GO TO 20	196
	IF (I1(J).NE.III) F1=-1.	197
	C(IJ) = C(IJ)+F1*ZLD(J1)	198
	GO TO 21	199
	20 IF (I3(J).NE.I3(I)) F1=-1.	200
	C(IJ) = C(IJ)+F1*ZLD(J2)	201
	21 CONTINUE	202
C	22 JJJ = JJ8	203
C	23 CONTINUE	204
C	RETURN	205
C		206
	24 FORMAT (3X,'AM = ',E10.3,3X,'DMAX = ',E10.3,3X,'DMIN = ',E10.3)	207
	25 FORMAT (1,'WARNING *****')	208
	1,' THIS PROBLEM EXCEED LIMIT OF THIN WIRE CONDITION, THE RESULTS	209
	2 ARE NOT CORRECT')	210
	END	211
		212
		213
		214

SORT

PURPOSE: to define the set of dipole modes.

METHOD: In the DO LOOP ending at statement 3, the set of dipoles is defined by filling the vectors I1(I) and I3(I) (the endpoints of dipole I); I2(I) (the terminal point of dipole I); and the vectors JA(I) and JB(I) (the monopoles comprising dipole I) with the node numbers and segment numbers, respectively. The DO LOOP ending at statement 8 determines MD(J,K) (the list of dipoles sharing segment J) and ND(K) (the number of dipoles sharing segment J).

CALLED BY: MAIN

CALLS TO: NONE

	SUBROUTINE SORT IIA,IB,II,I2,I3,JA,JB,MD,ND,NM,NP,N,MAX,MIN,ICJ,IN	1
	1 MI	2
	DIMENSION JSP(20)	3
	DIMENSION II(1), I2(1), I3(1), JA(1), JB(1)	4
	DIMENSION IA(1), IB(1), ND(1), MD(1)	5
	I = 0	6
C	DO 3 K=1,NP	7
	NJK = 0	8
C	DO 1 J=1,NM	9
	IND = (IA(J)-K)*(IB(J)-K)	10
	IF 1(IND.NE.0) GO TO 1	11
	NJK = NJK+1	12
	JSP(NJK) = J	13
1	CONTINUE	14
C	MOD = NJK-1	15
	IF (MOD.LE.0) GO TO 3	16
C	DO 2 IMD=1,MOD	17
	I = I+1	18
	IF (I.GT.ICJ) GO TO 2	19
	IPD = IMD+1	20
	JAI = JSP(IMD)	21
	JAI1 = JAI	22
	JBI = JSP(IPD)	23
	JBI1 = JBI	24
	II(II) = IA(JAI)	25
	IF (IA(JAI).EQ.K) II(1)=IB(JAI)	26
	I2(II) = K	27
	I3(II) = IA(JBI)	28
	IF (IA(JBI).EQ.K) I3(1)=IB(JBI)	29
2	CONTINUE	30
C	3 CONTINUE	31
C	N = 1	32
C	DO 4 J=1,NM	33
	ND(J) = 0	34
C	DO 4 K=1,4	35
4	MO(J,K) = 0	36
C	III = N	37
	IF (N.GT.ICJ) III = ICJ	38
C		39
		40
		41
		42
		43
		44
		45
		46
		47
		48
		49
	DO 8 I=1,III	50
	J = JA(I)	51
C	DO 7 L=1,2	52
	ND(J) = ND(J)+1	53
	K = 1	54
	M = 0	55
5	MJK = MO(J,K)	56
	IF (MJK.NE.0) GO TO 6	57
	M = 1	58
	MO(J,K) = 1	59
6	K = K+1	60
	IF (K.GT.4) GO TO 7	61
	IF (M.EQ.0) GO TO 5	62
7	J = JB(II)	63
C	8 CONTINUE	64
C	MIN = 100	65
	MAX = 0	66
C	DO 9 J=1,NM	67
	NDJ = ND(J)	68
	IF (NDJ.GT.MAX) MAX=NDJ	69
9	IF (NDJ.LT.MIN) MIN=NDJ	70
C	RETURN	71
	END	72
		73
		74
		75
		76

SQROT

PURPOSE: to solve the set of simultaneous equations to determine the currents on the thin wire structure.

METHOD: This subroutine considers the matrix equation $ZI = V$ which represents a system of simultaneous linear equations. NEQ denotes the number of simultaneous equations and the size of the matrix Z.

On entry to SQROT, S is the excitation column V. On exit, the solution I is stored in S. $Z(I,J)$ denotes the symmetric square matrix. Also on entry, the upper-right triangular position of $Z(I,J)$ is stored by rows in C(K) with

$$K = (I - 1) * NEQ - (I * I) / 2 + J .$$

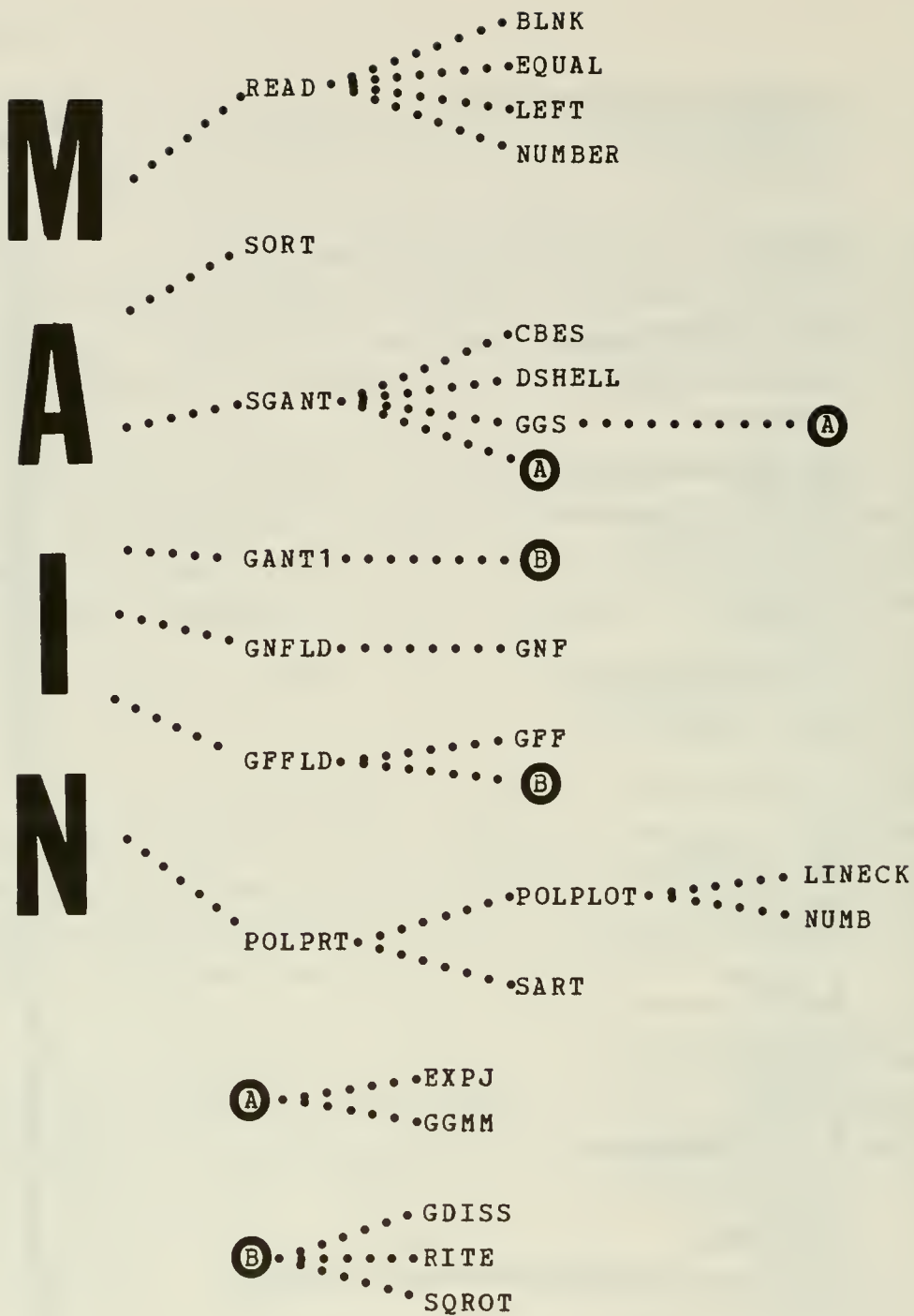
If I12 = 1, SQROT will transform the symmetric matrix into the auxiliary matrix (implicit inverse), store the result in C(K) and use the auxiliary matrix to solve the simultaneous equations. If I12 = 2, this indicates that C(K) already contains the auxiliary matrix.

The transformation from the symmetric matrix to the auxiliary matrix is accomplished in the DO LOOP ending at statement 5. The solution of the simultaneous equations is accomplished in the remainder of the program.

CALLED BY: GFPLD

CALLS TO: NONE

	SUBROUTINE SOROT (C,S,IMR,I12,NEQ)	1
	COMPLEX C(I1,S(I1)),SS	2
	N = NEQ	3
	IF (I12.EQ.2) GO TO 6	4
	C(I1) = CSQRT(C(I1))	5
C		6
	OO 1 K=2,N	7
1	C(KI) = C(KI)/C(I1)	8
C		9
C		10
	OO 5 I=2,N	11
	IMO = I-1	12
	IPO = I+1	13
	IO = I1-I1*N-I1*I-1)/2	14
	I1 = IO+1	15
C		16
	OO 2 L=1,IMO	17
	LI = I1-I1*N-I1*L-LI/2+1	18
2	C(LI) = C(LI)-C(LI)*C(LI)	19
C		20
	C(LI) = CSQRT(C(LI))	21
	IF (IPO.GT.N) GO TO 5	22
C		23
	OO 4 J=IPO,N	24
	IJ = IO+J	25
C		26
	OO 3 M=1,IMO	27
	MO = IM-I1*N-(M*N-MI/2	28
	MI = MO+1	29
	MJ = MO+J	30
3	C(IJ) = C(IJ)-C(MJ)*C(MI)	31
C		32
	4 C(IJ) = C(IJ)/C(I1)	33
C		34
	5 CONTINUE	35
C		36
	6 S(I1) = S(I1)/C(I1)	37
C		38
	OO 8 I=2,N	39
	IMO = I-1	40
C		41
	OO 7 L=1,IMO	42
	LI = I1-I1*N-(L*L-LI)/2+1	43
7	S(I1) = S(I1)-C(LI)*S(LI)	44
C		45
	I1 = (I1-1)*N-(I1-1)/2+1	46
8	S(I1) = S(I1)/C(I1)	47
C		48
	NN = ((N+1)*N)/2	49
	SINI = S(N)/C(INN)	50
	NMO = N-1	51
C		52
	OO 10 I=1,NMO	53
	K = N-I	54
	KPO = K+1	55
	KO = I(K-1)*N-(K*K-K)/2	56
C		57
	OO 9 L=KPO,N	58
	KL = KO+L	59
9	S(K) = S(K)-C(KL)*S(L)	60
C		61
	KK = KO*K	62
10	S(KI) = S(KI)/C(KK)	63
C		64
	IF I(WR.LE.0) GO TO 13	65
	CNOR = .0	66
C		67
	OO 11 I=1,N	68
	SA = CABS(S(I1))	69
11	IF (SA.GT.CNOR) CNOR=SA	70
C		71
	IF I(CNOR.LE.0.1) CNOR=1.	72
C		73
	OO 12 I=1,N	74
	SS = S(I1)	75
	SA = CABS(SS)	76
	SNOR = SA/CNOR	77
	PH = .0	78
	IF (SA.GT.0.) PH = 57.29578*ATAN2(AIMAG(SS),REAL(SS))	79
12	WRITE (6,14) I,SNOR,SA,PH,SS	80
C		81
	WRITE (6,15)	82
13	RETURN	83
C		84
	14 FORMAT (IX,I15,1F10.3,1F15.7,1F10.0,2F15.6)	85
	15 FORMAT (I10)	86
	END	87



CALLING SEQUENCE OF THE SUBROUTINES

SYMBOL DICTIONARY

A	characters of the input data cards
ABAP	backscattering phi plane angle for plotting
ABAT	backscattering theta plane angle for plotting
ABIP	bistatic scattering phi plane angle for plotting
ABIT	bistatic scattering theta plane angle for plotting
ACSP	absorption cross section for phi polarization
ACST	absorption cross section for theta polarization
AFFP	far-zone phi plane angle for plotting
AFFT	far-zone theta plane angle for plotting
AM	radius of the thin wire of the structure
BM	outer radius of the dielectric shell of the insulation of the wire
C	elements of the open-circuit impedance matrix
CG	branch currents for the structure
CGD	cosh γd for a given segment
CJ	loop currents for the structure
CMM	conductivity of the wire
D	length of a given segment
ECSP	extinction cross section for phi polarization
ECST	extinction cross section for theta polarization
EFF	radiation efficiency
EP	loop currents induced by a phi polarized wave
EPP	phi-polarized far-zone feild of the dipole mode
EPPS	scattered electric field in the phi direction due to a phi polarized wave
EPTS	scattered electric field in the theta direction due to a phi polarized wave
EP2	complex permittivity of insulation
EP3	complex permittivity of ambient medium
EP4	complex permittivity of ground
ERR	EP4/EP3
ER2	relative dielectric constant of insulation

ER3	relative dielectric constant of the ambient medium
ER4	relative dielectric constant of the ground
ET	loop current induced by a theta polarized wave
ETA	intrinsic impedance of ambient medium
ETPS	scattered electric field in the phi direction due to a theta polarized wave
ETT	theta polarized far-zone field of the dipole mode
ETTS	scattered electric field on the theta direction due to theta polarized wave
EX	near-zone electric field in x direction
EY	near-zone electric field in the y direction
EZ	near-zone electric field in z direction
E0	8.854E-12
FHZ	frequency in hertz
FMC	frequency in megahertz
GAM	intrinsic propagation constant of the ambient medium
GG	time-average power input
GPP	power gain associated with the phi polarized component
GTT	power gain associated with the theta polarized component
HGT	height of the structure above ground plane
IA	first node of a given segment
IB	second node of a given segment
IBISC	indicator for bistatic scatter calculations
ICARD	indicator for the data cards
ICJ	dimension corresponding to the number of simultaneous linear equations
IFLAG	indicator for program termination
IGAIN	indicator for antenna gain calculations
IGRD	indicator for presence of the ground plane
INC	indicator for the type of far-zone calculations
INEAR	indicator for near-zone calculations
INM	dimension corresponding to the number of monopoles
INT	number of integration steps

ISC	indicator for the insualtion
ISCAT	indicator for backscatter calculations
IWR	indicator for current distribution output
I1	endpoint node of a given dipole
I12	indicator for auxiliary matrix
I2	terminal node number of a given dipole
I3	endpoint node number of a given dipole
JA	first segment number of a given dipoile
JB	second segment number of a given dipole
KFLAG	print indicator
KGEN	list of generator/feed locations
LOAD	indicator for structure load
LZD	list of impedance/load locations
MAX	maximum of the number of segments connected to any one given node
MD	list of dipoles sharing a given segment
MIN	minimum of the number of segments that connected to any one given node
MSG	indicator for error printout
N	number of simultaneous linear equations
ND	total number of dipoles sharing a given segment
NGEN	indicator for antenna calculations
NM	number of segments
NPL	indicator for polar plot
OMEGA	angular frequency
PH	phi angle for far-zone calculations
SCSP	scattering cross section for phi polarization
SCST	scattering cross section for theta polarization
SGD	$\sinh \gamma d$ of a given segment
SIG2	conductivity of insulation
SIG3	conductivity of the ambient medium
SIG4	conductivity of ground
SPPM	echo area phi incident-phi scattered wave
SPTM	echo area phi incident-theta scattered wave
STPM	echo area theta incident-phi scattered wave
STTM	echo area theta incident-theta scattered wave

TD2	loss tangent of the insulation
TD3	loss tangent of ambient medium
TH	theta angle for far-zone calculations
TP	2π (6.28318)
UO	1.2566E-6
VG	antenna complex driving voltages
VOLT	list of VG's
X	x-coordinate of each node
XNP	list of XP's
XP	x-coordinate for near-zone calculations
Y	y-coordinate of each node
YNP	list of YP's
YP	y-coordinate for near-zone calculations
Y11	complex power input
Z	z-coordinate of each node
ZLD	complex load at a given node
ZLLD	list of ZLD's
ZNP	list of ZP's
ZP	z-coordinate for near-zone calculations
ZS	surface impedance of the wire
Z11	antenna input impedance

APPENDIX B
USER'S MANUAL

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USER'S MANUAL

The Antennas-Scatterers Analysis Program (ASAP) for thin wire structures in a homogenous conducting medium performs a frequency domain analysis of antennas and scatters. The program is applicable in the presence of either a perfect or a finite ground. This appendix will describe and explain the data cards necessary to execute the compute program. Although the program was written for the IBM 360 computer system, it can be executed on another system with minor modifications.

The program utilizes piecewise sinusoidal expansion for the current distribution with Kirchhoff Current Law enforced everywhere on the structure. If the structure contains end points, the currents at these points are assumed to vanish.

I. Program Limits

The thin wire assumptions are questionable and the accuracy and convergence deteriorate if the radius of wire utilized for the structure exceeds 0.01 of a wavelength, if the longest segment is greater than one-fourth of a wavelength, if the length ratio of the longest and shortest segments exceeds 100, or if the total wire length is less than 30 times the wire diameter. If a wire is bent sharply to form a small acute angle (less than 30 degrees), the thin wire model is questionable. It is assumed that the wire conductivity greatly exceeds the conductivity of the ambient medium. For insulated wires, the dielectric layer is assumed to be electrically thin.

II. Minimum Data

The minimum data necessary to execute the program is:

a. description of structure

b. radius of wire used for the structure

The program will default to the other parameters necessary.
The default parameters are:

a. wire for the structure is copper

b. frequency of operation is 300 mhz

c. homogeneous medium is free space

A more detailed explanation of the defaults will be discussed when the data card for the parameter is described.

III. Outputs

In antenna problems, the output includes structure currents, impedance(s) of feed(s), gain, polar radiation plots, and near field calculations. In bistatic scattering problems, the output includes structure currents, complex elements of the polarization scattering matrix, polar reradiation pattern plots, and echo areas produced by a plane wave. For backscattering problems the output includes absorption, scattering and extinction cross sections in addition to the outputs of bistatic scattering. Most of the outputs are suppressed and must be requested. Since the program can produce a large volume of output, care should be exercised until the user is familiar with the outputs.

IV. Data Cards

The Analysis Program utilizes free format for the data cards, that is, the program utilizes character recognition to determine which parameters are being read. Data placement (location) on the input card is not critical. Blank

characters, on all input cards but the COMMENT data card, are ignored and may be used at the discretion of the user. Since character recognition is used, only the first four characters of the key words must be present and correct.

The format for the COMMENT CARD utilizes standard FORTRAN format (i.e. 'C' in column 1 followed by at least four blanks). The COMMENT CARD is the only type of input card that position in the data block is critical. This (these) card(s) must be placed at the beginning of a data block. A data block is a series of related data cards. Several data blocks may be used to define an analysis problem. This will become clear when the termination cards (END, STOP, or CHANGE) are discussed. There is no limit to the number of comment cards that may be used. As a check for the user, all input data cards will appear on the output as they appear in the input deck.

The format of other data can be of one of two forms:

a. type of card (option 1/option 2/.....)

b. parameter (value) .

The type of format to use will be apparent as the individual data cards are discussed.

The numerical values for the parameters may be stated in any one of the following forms. The program will translate the number to the proper form for the specified parameter, either fixed or floating point. All of the following examples have the same value.

0.0001 or .0001 or 100.U or 100U or .1M or 0.1M or .0000001K

$$U = 10^{-6}$$

$$M = 10^{-3}$$

$$K = 10^3$$

1. WIRE This card is used to define the parameters associated with the wire utilized by the thin wire structure. Two options are available and are defined as:

RADIUS=value of the radius of the wire in meters

CONDUCTIVITY=value in megamhos per meters .

The wire data card must appear in the first data block to define wire radius. The default value of the conductivity is 50 megamhos/meter (copper).

```
WIRE( RADIUS=.001/ CONDU=28.5)
```

2. INSULATION This card is utilized to define the parameters associated with the insulation of the wire used for the structure to be analyzed. If this card is omitted, the program assumes that the structure is uninsulated. Four options are available and are defined as:

RADIUS=value of outer radius in meters

CONDUCTIVITY=value in micromhos per meter

DIELECTRIC=value of relative dielectric constant

LOSS TANGENT=value .

The conductivity and either the relative dielectric constant or the loss tangent (but not all three) options may be stated.

```
INSULATION ( RADIUS=.015/ COND=7./DIEL=5)
```

3. EXTERIOR MEDIUM This card is utilized to describe the homogeneous medium surrounding the structure. If the medium is free space, this card may be omitted. Three options are available and are defined as:

DIELECTRIC=value of relative dielectric constant

CONDUCTIVITY=value in micromhos per meter

LOSS TANGENT=value .

As with INSULATION card state either conductivity or loss tangent.

EXTE(LOSS=.45)

4. DESCRIPTION This card is utilized to describe the shape of the wire structure to the program. The user must divide the wire structure into segments of the appropriate length and number each node starting at one. A node is a point where a segment begins or ends. A maximum of four segments can meet at any given node. An isolated wire must contain at least two segments and three nodes. The structure is described by stating the node numbers that each segment connects. The description of a square loop might appear as:

DESCRIPTION (1-2/2-3/3-4/4-1) .

The description of a dipole and reflector might appear as:

DESCRIPTION (1-2/2-3/3-4/4-5/6-7/7-8/8-9/9-10) .

If the description will not fit on one data card continue on the next card as if the previous card were longer. The dipole example might appear as:

DESCRIPTION (1-2/2-3/3-4/4-5/
6-7/7-8/8-9/9-10) .

Note that the last character on the card to be continued is a slant (/). As many cards as necessary may be used. The maximum number of nodes permitted is fifty. If ground plane is present, the maximum number is twenty-five. If a ground plane is present and the structure touches the ground plane, the lowest node numbers MUST be used for the touching nodes. That is, if the structure touches the ground plane at two points, node numbers 1 and 2 MUST be assigned to these nodes.

DESCR (1-2/2-3/3-4/4-1)

5. GEOMETRY This card is used to state the physical location in rectangular coordinates of each node of the DESCRIPTION CARD . The rectangular grid is in units of meters. If node 1 is located at x_1, y_1, z_1 and node 2 at x_2, y_2, z_2 and node 3 at x_3, y_3, z_3 , etc., the GEOMETRY CARD might appear as:

GEOMETRY($x_1, y_1, z_1/x_2, y_2, z_2/x_3, y_3, z_3/.....$)

As with the DESCRIPTION CARD, continuation cards are permitted.

```
GEOM(.1,0,.1/-.1,0.1/-.1,0-.1/.1,0,-.1)
```

6. FEED For antenna analysis the feed point(s) and voltage(s) must be stated. In the foremention dipole and reflector example if the feeds were at node 2 with a voltage source of .5 at an angle of -90 degrees and at node 4 with a voltage source of .5 at an angle of +90 degrees the FEED CARD might appear as:

```
FEED(2,.5,-90/4,.5,+90)
```

The order of the information for each voltage source is node number, magnitude, and phase angle. This order is repeated until all sources are stated. If the source information will not fit on one card, use another card similiar to the initial one; that is, repeat the word "FEED". If only one voltage source is applied to the structure, only the node number must be stated. In the dipole example, if the drive is at node 3, the FEED CARD might appear as:

```
FEED(3)
```

A default source of one voltage at zero degree phase is assumed. Voltage sources should only be stated for nodes with only two segments.

```
FEED(2,.5,-90/4,.5,+90)
```


7. LOAD This card is used to describe the loads to be placed at various locations on the structure. The format for this card is similiar to that of the FEED CARD, that is, the word "LOAD" is used in the place of "FEED". The order of the information on the card is the same. Since this card is frequency dependent, it must be changed if the frequency of operation is changed. No default parameters are available. The structure is assumed unloaded unless this card is used. Once the structure is loaded, it will remain loaded for the remainder of the data block series. To unload the structure the following card may be used:

LOAD(-1)

LOAD(1,120,-45/3,120,+45)

8. OUTPUT This card is used to request output data. Most of the output is in tabular form. More than one OUTPUT CARD is permitted per data block, but not for the same type of output. If only the antenna input impedance, antenna efficiency, or time-average power input is of interest, no OUTPUT CARD is necessary. These parameters are automatically printed if a FEED CARD or GENERATOR CARD is utilized. One or more of the following options may be used to request the various outputs available.

FAR FIELD=phi initial, phi final, theta initial, theta final

This option gives the components of the electric field intensity in the far field as phi and theta varies between limits specified in one degree divisions.

BACKSCATERING=phi initial, phi final, theta initial, theta final

This option gives the absorption, scattering, and extinction cross sections, and the complex elements of the polarization scattering matrix for an incident plane wave illuminating the structure from the spherical direction of phi, theta as both vary between limits specified in one degree divisions.

BISTATIC=phi initial, phi final, theta initial, theta final

This option gives echo area and the complex elements of the polarization scattering matrix for an incident plane wave illuminating the structure from the spherical direction phi, theta final of the backscattering output option, reradiated in the phi, theta direction as both vary between limits specified in one degree divisions. A bistatic output request must be accompanied with a backscattering request in the same data block.

STEP=value in degrees

This option will cause any of the above output options to be stepped at a different interval size. That is, if one of the above options is to be stepped at ten degrees intervals, use this option. This option overrides the one degree stepping.

CURRENT

This option gives the currents on the structure which are produced by the feed/generator voltages and/or the incident plane wave of the backscattering request.

NEAR=x1,y1,z1

or

NEAR=(x1,y1,z1/x2,y2,z2/x3,y3,z3/etc.....)

This option gives the value of electric field components in the near field for the antenna at the point or points specified.

OUTPUT (FARF=45,50,25,50)

9. PLOT This card will produce normalized polar plots in the specified plane for the stated option. The plane is specified by stating either "PHI=____" or "THETA=____". The PLOT CARD overrides the limits of the OUTPUT CARD for the same option. If only a normalized pattern is of interest, only a PLOT CARD is necessary. If a table of values and a normalized pattern is desired, both a PLOT CARD and OUTPUT CARD must be used. Only one PLOT CARD is permitted per data block. The following pattern plots are available:

FAR FIELD/plane

This option will plot the far field intensity for each component of the electric field.

BACKSCATTERING/plane

This option will plot the normalized magnitude of each of the elements of the polarization scattering matrix.

BISTATIC/plane

This option will plot the normalized magnitude of each of the elements of the polarization scattering matrix produced by the incident plane wave stated by final limits of the backscattering option of the output request.

PLOT (FARF/THET=90)

10. GROUND This card is used to describe the ground parameters if a ground plane is present. If no ground plane is present, the structure is assumed to be in free space or the homogeneous medium of the EXTERIOR MEDIUM data card. Seven options are available and are defined as:

PERFECT

This option will analyze the structure over a perfect ground plane.

GOOD

This option will analyze the structure over a good ground plane where the conductivity of the ground is .02 mhos/meter and the relative dielectric constant is 30.

POOR

This option will analyze the structure over a poor ground plane where the conductivity of the ground is .001 mhos/meter and the relative dielectric constant is 4.

SEA

This option will analyze the structure over salt water where the conductivity of the water is 4. mhos/meter and the relative dielectric constant is 80.

HEIGHT=value in meters

This option will analyze the structure with origin of the GEOMETRY card this height above the ground plane. The lowest point of the structure must not lie below the ground plane. It may lie on the ground plane.

CONDUCTIVITY= value in mhos/meter

This option is used to state the value of conductivity of the ground plane if the default values mentioned above are not utilized.

DIELECTRIC= value

This option is used to state the relative dielectric constant of the ground plane if the default values mentioned above are not utilized.

GROUND (HEIG=10/COND=.002/DIEL=10)

11. INTERVAL FOR CALCULATION This card is used to state the number of intervals to be used for calculating the elements of the impedance matrix with Simpson's-rule integration. A large value for the number improves the accuracy at the expense of greater execution time. For most problems a suitable combination of speed and accuracy is obtained with a value of four, the default value. If the rigorous closed-form impedance expressions in terms of the exponential integrals is desired, set this value to zero.

INTERVAL=value

INTE(6)

12. GENERATOR This card is similiar to the FEED CARD in use, except that the segment numbers are stated instead of the node numbers. This is useful if thre or four segments meet at a node. The positive terminal of the generator is connected to the specified segment such that current is forced in the the positive direction. The positive direction of current flow is from the first stated node number of that segment toward the second stated as ordered on the DESCRIPTION CARD.

GENE(2,.5,-90/4,.5,+90)

13. IMPEDANCE This card is similiar to the LOAD CARD in use, except that the segment numbers are stated instead of the node numbers. As with the GENERATOR CARD, this is used if three or four segments are connected to a node. The impedance will be connected to the positive terminal of the specified segment. The format of this card is the same as the LOAD CARD.

IMPE(1,120,-45/3,120,+45)

14. CHANGE This card at the end of the data block signals the program that the following data cards are changes to the previously read data, for the next run. If a "CHANGE CARD" is used, the outputs must be requested again in the next data block.

15. END This card signals the program that this is the end of a data block series and to reinitialize data for the next problem. An "END CARD" cannot be used with a "CHANGE CARD".

16. STOP This card signals the program that all of the data cards have been read and to terminate itself when execution is completed. This card must be used as the last card in place of the "END CARD" of the last data block series. A "STOP CARD" cannot be used with an "END CARD" in the same data block.

```

C      AN EXAMPLE PROBLEM
C
C      V ANTENNA
C
WIRE(RADIUS=1M)
GEOM(0,-.18,+.18/0,-.09,+.09/0,0,0/0,0.09,.09/0,.18,.18)
DESC(1-2/2-3/3-4/4-5)
FEED(3)
OUTPUT(FARF=45,50,65,80/STEP=5)
CHANGE
OUTPUT(BIST=45,45,45,45/BACK=0,0,10,12)
OUTPUT(CURRENT)
CHANGE
C
C      CHANGE STRUCTURE SHAPE TO DIPOLE
C
GEOM(0,-.25,0/0,-.125,0/0,0,0/0,.125,0/0,.25,0)
PLOT(FARF/PHI=90)
GROUND(HEIGHT=.25/GOOD)
STOP

```

THE ABOVE DATA DECK WILL PRODUCE THE OUTPUT ON THE
FOLLOWING PAGES.

 * FAR FIELD *
 * CALCULATIONS *

DEGREES THETA	PHI	POWER THETA	GAIN PHI	REAL	IMAG	THETA	INTENSITY MAGN	PHASE	REAL	IMAG	PHI	MAGN	PHASE
65.0	45.0	0.214E 00	0.663E 00	-.2811E 00	-.1596E 00	0.323E 00	0.323E 00	-150.4	-.2145E 00	-.5278E 00	0.569E 00	0.569E 00	-112.1
70.0	45.0	0.1819E 00	0.6335E 00	-.2802E 00	-.998E -01	0.297E 00	0.297E 00	-160.4	-.2315E 00	-.51194E 00	0.5685E 00	0.5685E 00	-114.0
75.0	45.0	0.1554E 00	0.611E 00	-.2727E 00	-.395E -01	0.275E 00	0.275E 00	-171.7	-.2484E 00	-.5104E 00	0.5676E 00	0.5676E 00	-116.9
80.0	50.0	0.1365E 00	0.6591E 00	-.2571E 00	0.198E -01	0.257E 00	0.257E 00	-175.6	-.2654E 00	-.5078E 00	0.5668E 00	0.5668E 00	-117.9
85.0	50.0	0.1248E 00	0.708E 00	-.2328E 00	-.1710E 00	0.3478E 00	0.3478E 00	-150.5	-.1933E 00	-.4574E 00	0.519E 00	0.519E 00	-114.1
75.0	50.0	0.2101E 00	0.378E 00	-.3017E 00	-.1066E 00	0.320E 00	0.320E 00	-171.5	-.2088E 00	-.4591E 00	0.5107E 00	0.5107E 00	-116.0
70.0	50.0	0.1799E 00	0.5352E 00	-.2931E 00	-.4191E -01	0.294E 00	0.294E 00	-175.5	-.2238E 00	-.4503E 00	0.5097E 00	0.5097E 00	-117.9
65.0	50.0	0.1581E 00	0.5331E 00	-.2767E 00	0.2190E -01	0.277E 00	0.277E 00						

CONTINUE EXECUTION WITH THE FOLLOWING ADDITIONS AND/OR CHANGES

DATA CARDS

7 OUTPUT(81ST=45,45,45,45/BACK=0,0,10,12)
8 OUTPUT(CURRENT)
9 CHANGE

* INPUT DATA *

* OUTPUT REQUESTED *

STRUCTURE CURRENTS
BACKSCATTERING FOR PHI VARYING FROM 0.0 TO 0.0 AND THETA VARYING FROM 10.0 TO 12.0
IN STEPS OF 1.0 DEGREES.
BISTATIC SCATTERING FOR PHI VARYING FROM 45.0 TO 45.0 AND THETA VARYING FROM 45.0 TO 45.0
IN STEPS OF 1.0 DEGREES.

 *
 * ANTENNA
 * CALCULATIONS
 *
 *

THE INPUT IMPEDANCE AT NODE 3 IS 46.2782898 + J 26.5534973

ANTENNA BRANCH CURRENTS

SEG	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	1	0.0	0.0	0.0	0.0	0.0	2	0.12023E-01	-.79175E-02	0.14396E-01	0.76810E 00	-33.4
2	2	0.12023E-01	-.79175E-02	0.14396E-01	0.76810E 00	-33.4	3	0.16256E-01	-.93276E-02	0.18742E-01	0.10000E 01	-29.8
3	3	0.16256E-01	-.93276E-02	0.18742E-01	0.10000E 01	-29.8	4	0.12023E-01	-.79175E-02	0.14396E-01	0.76810E 00	-33.4
4	4	0.12023E-01	-.79175E-02	0.14396E-01	0.76810E 00	-33.4	5	0.0	0.0	0.0	0.0	0.0

THE RADIATION EFFICIENCY IS 99.5343018

THE TIME-AVERAGE POWER INPUT IS 0.0162564

THE ANTENNA IMPEDANCE IS 46.2782898 + J 26.5534973

 * BACKSCATTERING *
 * CALCULATIONS *
 * *****

BRANCH CURRENTS ASSOCIATED WITH PLANE-WAVE SCATTERING FOR THE INCIDENT ANGLES, PHI= 0.0 AND THETA= 10.0

CURRENTS INDUCED BY THE PHI POLARIZED WAVE

SEG	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	MODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	1	0.0	0.0	0.0	0.0	0.0	2	0.31772E-02	-0.49074E-03	0.32149E-02	0.73326E-00	-8.8
2	2	0.31772E-02	-0.49074E-03	0.32149E-02	0.73326E-00	-8.8	3	0.43371E-02	-0.64178E-03	0.43844E-02	0.10000E-01	-8.4
3	3	0.43371E-02	-0.64178E-03	0.43844E-02	0.10000E-01	-8.4	4	0.31772E-02	-0.49073E-03	0.32149E-02	0.73326E-00	-8.8
4	4	0.31772E-02	-0.49073E-03	0.32149E-02	0.73326E-00	-8.8	5	0.0	0.0	0.0	0.0	0.0

CURRENTS INDUCED BY THE THETA POLARIZED WAVE

SEG	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	MODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	1	0.0	0.0	0.0	0.0	0.0	2	-0.16843E-04	0.28762E-04	0.3331E-04	0.9999E-00	120.4
2	2	-0.16843E-04	0.28762E-04	0.3331E-04	0.9999E-00	120.4	3	0.44943E-09	-9.5513E-11	0.44958E-09	0.13488E-04	-1.2
3	3	0.44943E-09	-9.5513E-11	0.44958E-09	0.13488E-04	-1.2	4	0.16844E-04	-0.28762E-04	0.3332E-04	0.10000E-01	-59.6
4	4	0.16844E-04	-0.28762E-04	0.3332E-04	0.10000E-01	-59.6	5	0.0	0.0	0.0	0.0	0.0

BRANCH CURRENTS ASSOCIATED WITH PLANE-WAVE SCATTERING FOR THE INCIDENT ANGLES, PHI= 0.0 AND THETA= 11.0

CURRENTS INDUCED BY THE PHI POLARIZED WAVE

SEG	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	MODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	1	0.0	0.0	0.0	0.0	0.0	2	0.31773E-02	-0.49499E-03	0.32156E-02	0.73328E-00	-8.9
2	2	0.31773E-02	-0.49499E-03	0.32156E-02	0.73328E-00	-8.9	3	0.43372E-02	-0.64765E-03	0.43853E-02	0.10000E-01	-8.5
3	3	0.43372E-02	-0.64765E-03	0.43853E-02	0.10000E-01	-8.5	4	0.31773E-02	-0.49499E-03	0.32156E-02	0.73328E-00	-8.9
4	4	0.31773E-02	-0.49499E-03	0.32156E-02	0.73328E-00	-8.9	5	0.0	0.0	0.0	0.0	0.0

CURRENTS INDUCED BY THE THETA POLARIZED WAVE

SEG	NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE	MODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	1	0.0	0.0	0.0	0.0	0.0	2	-0.18455E-04	0.31643E-04	0.36631E-04	0.99998E-00	120.2
2	2	-0.18455E-04	0.31643E-04	0.36631E-04	0.99998E-00	120.2	3	0.53724E-09	-1.5861E-09	0.56016E-09	0.15222E-04	-16.4
3	3	0.53724E-09	-1.5861E-09	0.56016E-09	0.15222E-04	-16.4	4	0.18455E-04	-0.31644E-04	0.36632E-04	0.10000E-01	-59.7
4	4	0.18455E-04	-0.31644E-04	0.36632E-04	0.10000E-01	-59.7	5	0.0	0.0	0.0	0.0	0.0

BRANCH CURRENTS ASSOCIATED WITH PLANE-WAVE SCATTERING FOR THE INCIDENT ANGLES, PHI= 0.0 AND THETA= 12.0

CURRENTS INDUCED BY THE PHI POLARIZED WAVE

SEG NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	0.0	0.0	0.0	0.0	0.0	0.31775E-02	-4.9965E-03	0.32165E-02	0.73330E-00	-8.9
2	0.0	-4.9965E-03	0.32165E-02	0.73330E-00	-8.9	0.43373E-02	-6.5407E-03	0.43863E-02	0.10000E-01	-8.6
3	0.0	-6.5407E-03	0.43863E-02	0.10000E-01	-8.6	0.31775E-02	-4.9964E-03	0.32165E-02	0.73330E-00	-8.9
4	0.0	-4.9964E-03	0.32165E-02	0.73330E-00	-8.9	0.0	0.0	0.0	0.0	0.0

CURRENTS INDUCED BY THE THETA POLARIZED WAVE

SEG NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE NODE	REAL	IMAGINARY	MAGNITUDE	NORMALIZED MAGNITUDE	PHASE
1	0.0	0.0	0.0	0.0	0.0	-2.0044E-04	0.34526E-04	0.39922E-04	0.99998E-00	120.1
2	-2.0044E-04	0.34526E-04	0.39922E-04	0.99998E-00	120.1	0.57514E-09	-2.6965E-09	0.63522E-09	0.15911E-04	-25.1
3	0.57514E-09	-2.6965E-09	0.63522E-09	0.15911E-04	-25.1	0.20045E-04	-3.4526E-04	0.39923E-04	0.10000E-01	-59.9
4	0.20045E-04	-3.4526E-04	0.39923E-04	0.10000E-01	-59.9	0.0	0.0	0.0	0.0	0.0

BACK SCATTERING
POLARIZATION SCATTERING MATRIX
(INCIDENT - SCATTERED)

INCIDENT PLANE	PHI	THETA	PHI-PHI	IMAG	REAL	PHI-THETA	IMAG	REAL	THETA-PHI	IMAG	REAL	THETA-THETA
0.0	0.0	10.0	0.47452E-01	-1.8107E-00	0.18626E-08	-1.4901E-07	-1.4901E-07	0.69849E-08	-1.9325E-07	0.93990E-04	0.17389E-03	0.21566E-03
0.0	0.0	11.0	0.47001E-01	-1.8128E-00	-7.4506E-08	-1.4901E-07	-1.4901E-07	0.25611E-08	-2.5611E-07	0.11430E-03	0.21566E-03	0.21566E-03
0.0	0.0	12.0	0.46506E-01	-1.8150E-00	-7.4506E-08	-1.4901E-07	-1.4901E-07	0.13970E-08	-2.9337E-07	0.113677E-03	0.21566E-03	0.21566E-03

FOR BISTATIC SCATTERING THE INCIDENT
PLANE WAVE IS $\text{PHI} = 0.0$ $\text{THETA} = 12.0$

1208
OBSERVATION
POINT
PHI THETA
45.0 45.0

CONTINUE EXECUTION WITH THE FOLLOWING ADDITIONS AND/OR CHANGES

C CHANGE STRUCTURE SHAPE TO OIPOLE
C

DATA CARDS

10 GEOM(0,-.25,0/0,-.125,0/0,0,0/0,.125,0/0,.25,0)
11 PLOT (FAR/PHI=90)
12 GROUND(HEIGHT=.25/G000)
13 STOP

* INPUT DATA *

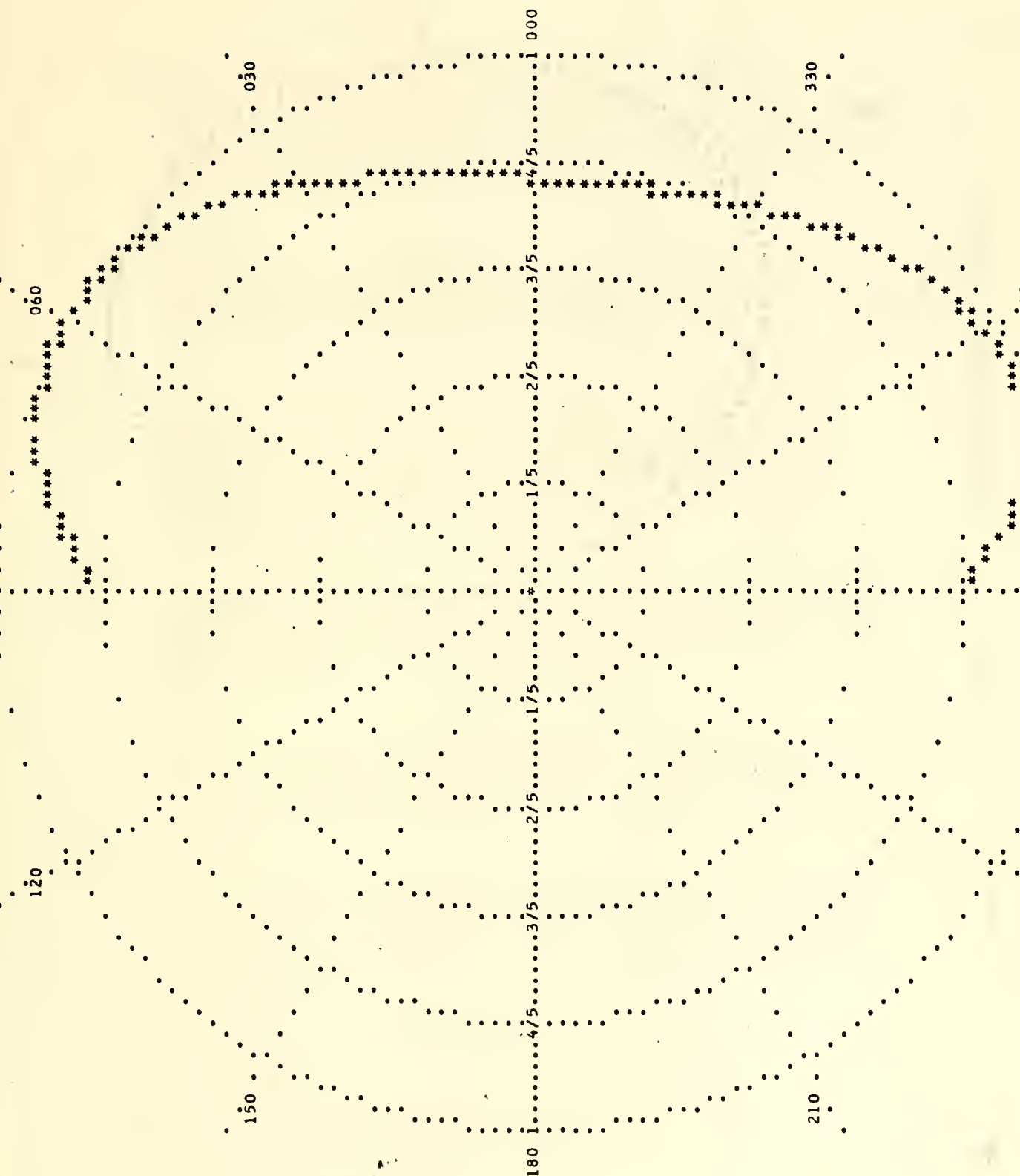
GROUND PLANE (NO/YES) YES
GROUND DIELECTRIC CONSTANT (RELATIVE) 0.3000E 02
GROUND CONDUCTIVITY (MHOS/METER) 0.2000E-01
ANTENNA HEIGHT (METERS) 0.25000E 00

SEG			WIRE STRUCTURE			LOCATION			LOCATION		
NO.	NO.	NO.	NO.	NO.	NO.	X	Y	Z	X	Y	Z
1	1	1	1	1	1	0.0	0.0	0.0	0.0	-0.12500E 00	0.0
2	2	2	2	2	2	0.0	0.0	0.0	0.0	0.0	0.0
3	3	3	3	3	3	0.0	0.0	0.0	0.0	0.12500E 00	0.0
4	4	4	4	4	4	0.0	0.0	0.0	0.0	0.25000E 00	0.0

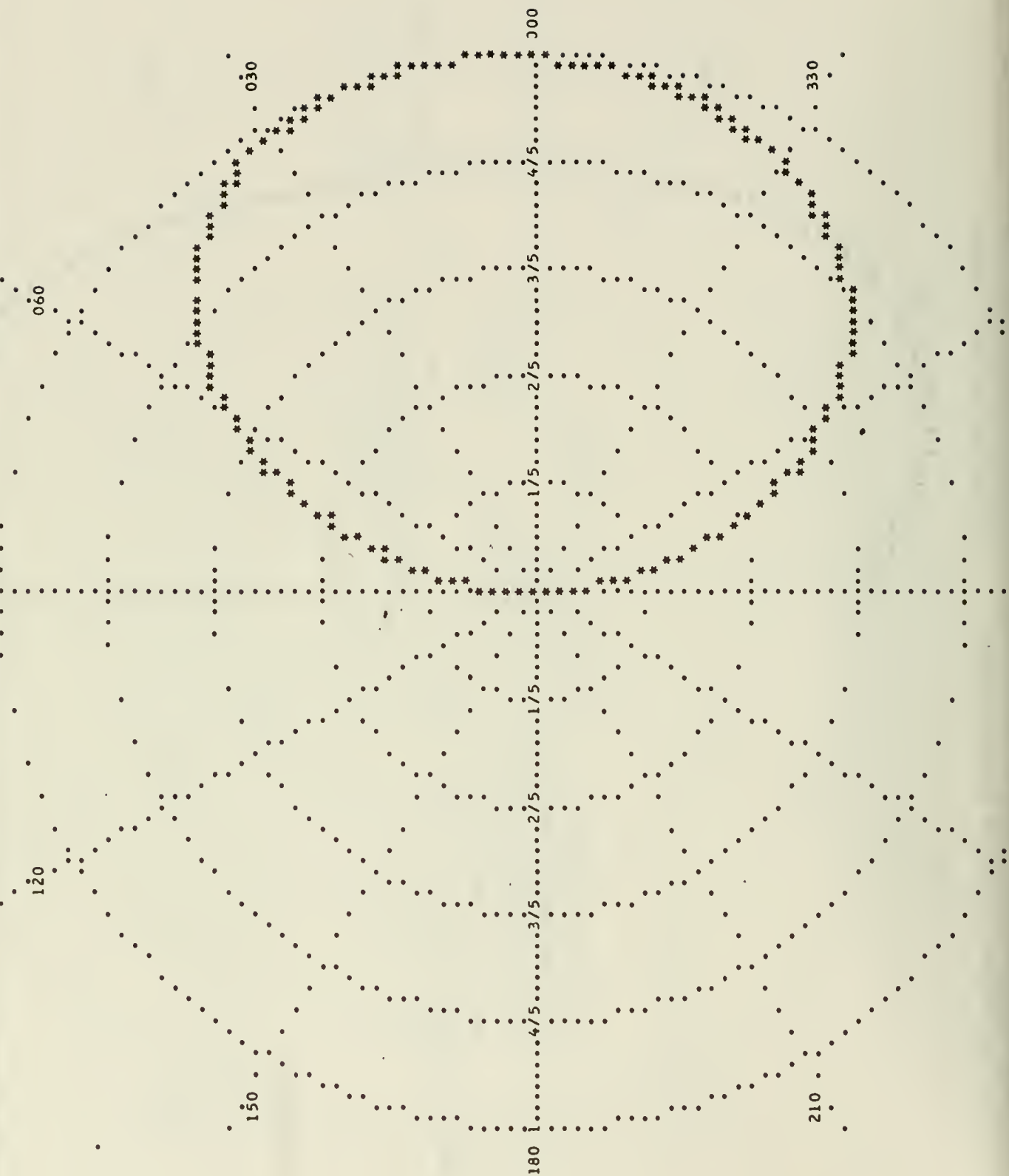
* OUTPUT REQUESTED *

PLOT FOR FAR FIELD PHI= 90.0

PHI ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLANE.



THE ELECTRIC FIELD ANTENNA PATTERN FOR SPECIFIED PLANE. NORMALIZING FACTOR= .42801E 00



LIST OF REFERENCES

1. Richmond, J.H., "Radiation and Scattering by Thin-Wire Structures in the Complex Frequency Domain," Report 2902-10, July, 1973, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Grant NGL 36-008-138 for National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia 23365.
2. (a) Richmond, J.H., "Computer Program for Thin-Wire Structures in a Homogeneous Conducting Medium," NASA Contractor Report CR-2399, June 1974, for sale by the National Technical Information Service, Springfield, Virginia, 22151, Price \$3.75.
- (b) Richmond, J.H., "Computer Program for Thin-Wire Structures in a Homogeneous Conducting Medium," Report 2902-12, August 1973, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering prepared under Grant NGL 36-008-138 for National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia 23665.
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4. Miller, E.K., Poggio, A.J., Burle, G.J., and Selden, E.S., "Analysis of Wire Antennas in the Presence of a Conducting Half Space: Part I. The Vertical Antenna in Free Space," Canadian Journal of Physics, 50, pp 879-888.
5. Miller, E.K., Poggio, A.J., Burle, G.J., and Selden, E.S., "Analysis of Wire Antennas in the Presence of a Conducting Half Space: Part II. The Horizontal Antenna in Free Space," Canadian Journal of Physics, 50 pp 2614-2627.

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